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BY J. F. L.

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PREFACE.

The lighting of railway carriages by electricity is a subject which has been brought into prominence recently, owing to the remarks made by the Board of Trade inspectors in connection with their enquiries into railway accidents at which fires took place, notably that occurring at Aisgill (Midland Railway) in September, 1913.

Following this accident, fire broke out among the wreckage, and a number of passengers were burned to death. A considerable amount of discussion took place in the press after the accident, the popular voice being raised against gas as an illuminant, and electric lighting was demanded. It was apparent, however, that the majority of its advocates had but a very superficial knowledge of the subject. They simply insisted that electricity should be substituted for gas forthwith, the financial, electrical, and mechanical considerations which have such an important bearing upon the subject, being ignored.

Although it appeared to these critics a very simple matter to electrically light a train, the subject presents certain difficulties which cannot be so conveniently disposed of.

In the following pages the general considerations governing the electric lighting of railway carriages will be discussed; and the chief features of the leading systems or methods at work on railways described.

Other systems are at work on a small scale, or in the experimental stage, but those described are systems which are in every-day use.

CONTENTS.

GENERAL CONSIDERATIONS.

The voltage or pressure of the current delivered by a dynamo depends upon the speed at which the armature revolves, and as a train obviously travels at varying speeds during its journey, an ordinary dynamo driven by belt from a pulley on an axle, would deliver current at varying voltages, of which only one would be suitable for the lamps ; lower voltages only partially lighting them, while higher voltages would burn them out.

Evidently, then, the first consideration must be to provide either a dynamo alone, or some apparatus in conjunction with it, which will so regulate or govern the voltage, that it will remain approximately constant whatever the speed of the train.

Provision must also be made for continuity of current, for evidently when the train stopped the dynamo would cease to generate current, and the lights would go out. To overcome this difficulty a battery of accumulators is usually provided to supply the lights when the train is at rest.

On account of batteries being used it is necessary that current should always be supplied to the circuit in one direction, irrespective of the direction of rotation of the dynamo armature.

The dynamo must only be connected with the battery when it is capable of charging the latter, while when the dynamo is stopped or running at an insufficient speed to generate a charging voltage, it must be disconnected from it. If this were not done the battery would discharge through the dynamo and seriously damage it. A switch capable of "cutting in" or "cutting out" the dynamo must therefore be provided. The dynamo must be totally enclosed from dust, water or atmospheric influences, although arranged for instant examination of its bearings, commutator, etc., when required.

The battery must be of suitable construction for the work required of it, and should be so arranged as to be very quickly examined.

The above requirements do not present any insuperable difficulty, but the means adopted for dealing with them by the inventors of the various systems are varied and interesting, while the fact that such a large number of systems are in regular work in various parts of the world, proves them to be as a rule reliable and efficient.

In considering the lighting of a railway carriage by electricity, some knowledge is required of the conditions imposed by the demands of traffic.

If a train is running on a special service or marshalled in a certain order, which is always adhered to, the lighting problem becomes easier than when the train is composed of vehicles which are attached or detached at various points on the journey. In the former case some central supply of power can be provided on the train, from which each carriage derives its light, through connections being provided.

In the early history of electric train lighting this was the method usually adopted. In October, 1881, the London, Brighton and South Coast Railway made an experimental trial of lighting a Pullman car on the run between London and Brighton. Twelve "Swan" carbon filament incandescent lamps were used, current being supplied by a battery of 32 "Faure" cells, each weighing 45½ lbs. and capable of supplying light for about 6 hours. The battery was carried underneath the carriage, and had to be removed every night for charging. This was probably the first recorded attempt to electrically light a railway carriage, and great credit is due to the railway company for their initiative, especially when it is considered that both the "Faure" cell and the incandescent lamp were in their infancy.

The London, Brighton and South Coast Railway also fitted a new Pullman car train of 4 cars with electric light in

December, 1881. 29 lamps of 10 candle power each were used, current being supplied by Faure batteries, as in the earlier carriage.

About the same time (1881) the North British Railway equipped a train with electric lamps, the current being supplied from a small "Brotherhood" steam engine and dynamo fixed on the locomotive. Although more or less successful, the steam consumption was too great, for the device to be adopted.

In 1883 the L.B. & S.C. Railway fitted up 3 trains with Stroudley's system of lighting, which consisted of a dynamo in the guard's van, driven from one of the axles by means of a belt through the floor. A lead battery was used in connection with the equipment, which was in the care of the guard and operated by him.

The system was so successful that the railway company decided to continue it, and during the next few years 20 trains were similarly equipped.

From this time until 1894 other railways also experimented in the same direction, either with batteries alone, or steam-driven generators on engines or tenders without batteries, or some combination of the two. The electric light was liked by passengers, and it was considered desirable to adopt it on independent carriages which could be attached to or removed from the train at any point. For some time nothing was found suitable, but in 1894 Messrs. J. Stone & Co. patented their single battery system, this being followed in 1896 by their double battery system. Its success was at once assured, and a number of trains were fitted, the earlier ones being on the Great Northern Railway of Ireland and the London, Tilbury and Southend Railway.

Since that date many systems have been introduced, and electric lighting of separately equipped carriages is now common on almost every railway in the British Isles and a large number abroad, while its use is extending.

Many trains are still equipped with installations which supply current to more than one carriage, "block" trains as used on most of the suburban services of large English cities have either two or three generators and sets of batteries distributed along the train, each lighting three or four carriages.

On the Great Western Railway the "Brake Vehicle" system has been largely adopted and developed. In this system a number of brake vans are fitted with an electric lighting equipment capable of lighting, say, four carriages. A large number of carriages are fitted with through wiring and lamps only, and since two brake vans at least are usually included in the composition of a train, it is evident that a supply of current is always available, and on coupling up the end connections provided on each carriage, the two brake vans would light eight carriages.

A separately equipped carriage can, of course, run anywhere, as it has its own generator and battery, which if well maintained and the vehicle kept on fairly regular services will give little trouble. On long slow runs, constant night running, standing out of service for long periods or other irregular treatment (which, however, at times cannot be avoided), battery troubles are likely to occur, and a few notes on this aspect of the case are given in the succeeding pages.

The question of expense may be briefly touched upon, although the actual cost of maintaining an electrically-lighted carriage, when all expenses are considered, is difficult to arrive at.

As far as initial equipment is concerned, electric light is considerably more expensive than a gas equipment, and this must of necessity be the case, for a dynamo and battery have to be provided, and these are more expensive details than a gas cylinder and regulator. It must not be forgotten, however, that the carriage equipped for gas lighting does not generate the light as an electrically lighted one does. It is dependent for its periodical supply of gas upon stationary gas works, travelling reservoirs and station mains, and the cost of these accessories must be debited to the cost of lighting

by gas. The depreciation on these details is, however, lower than on electrical material.

The electrically-lighted vehicle generates its own supply of illuminant without any extraneous charges, except the cost of the coal used in hauling the carriage, but this, however, cannot be very accurately determined.

It is evident, however, that a dynamo delivering, perhaps 2 horse power, to batteries and lamps must be absorbing nearly double this amount, but the quantity of coal used per train mile by the engine being a variable quantity, owing to the state of the weather and other causes, no definite figure can be stated as that due to driving the dynamos on a train.

Even when dynamometer car tests are made the results are very erratic, but it might be accepted that from 8lbs. to 10lbs. of extra coal per hour are burnt when hauling an electrically-lighted carriage as compared with a gas-lighted one.

Before describing the various systems in use, the usual arrangement of dynamo, battery and fittings may be mentioned.

Dynamo Suspension. As the dynamo receives its rotary motion from the carriage axle, it is necessary that it should be in proximity to it. In some cases, as in brake vans serving several carriages, it may be placed inside the vehicle, the belt being passed through the floor, but it is usually suspended from the carriage underframe at a horizontal distance of from 5 to 10 feet from the centre of the axle, the exact distance depending upon circumstances. A drive of short centres causes great wear on the belt however, and should be avoided where possible.

Special members are fixed to the underframe so that the weight of the dynamo is distributed over the framing. The dynamo should be suspended so that the lower portion of the carcase is at least 8 inches above rail level, otherwise it is liable to be struck by heaped up ballast or other obstructions placed between the rails.

In some cases guards are used which hang down in front of the dynamo and prevent it from being struck by flying ballast, etc., and also shields it from mud thrown up by the wheels.

Theoretically it would appear that the dynamo should be suspended from the bogie so that variations of belt tension; due to the bogie taking curves, might be obviated, but in practice, difficulties are introduced. The dynamo having to be bracketed out from the bogie, introduces severe strains on the brackets and bogie headstocks, the whole weight of the dynamo having to be thrown over on the bogie taking a curve, while the extra weight on the adjacent wheel and spring causes trouble, unless the dynamo is arranged to hang in the centre, when it is difficult and dangerous to inspect.

Safety chains should always be provided, in case of suspension bolts or links breaking.

The axle pulley, which is of cast iron or pressed steel, is clamped to the axle as shewn in Fig. 1, and requires to be

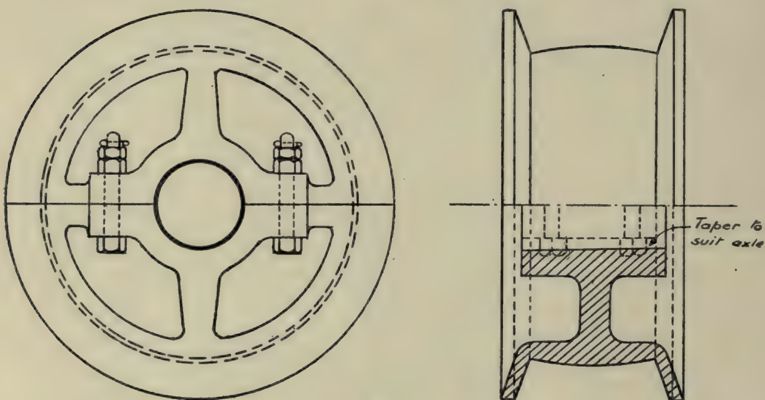


Fig. 1.

carefully fitted and fixed, as serious damage would be caused were the two halves to come apart when running. The diameter is usually from 15 to 22 inches, and depends upon

the ratio of the number of revolutions which the dynamo is required to make to that of the running wheel.

The diameter should not be too large, otherwise it is liable to be fouled by obstructions and broken. Some railways make the pulley of cast steel, and press it upon the axle before the wheels are put on, this makes a reliable job, but demands a number of similarly fitted spare wheels and axles distributed over the line in case of hot boxes arising.

The profile of the pulley face should be as shown in Fig. 1, slightly " crowned " and the face should be about 1½ inches wider than the belt used. Straight flanges introduce excessive friction on the belt edges, unless the pulley face is abnormally wide.

Belts. These are a troublesome item, various materials are recommended, but the heavy work they are subjected to causes rapid deterioration ; unless the axle pulley and dynamo pulley are truly in line, excessive flange wear takes place, the axle pulley being liable to " creep " on the axle, unless looked to and kept tight.

It is an advantage to hang the dynamo slightly out of parallelism with the axle, so that the belt pull will pull it parallel, there being usually slight play in the dynamo suspension gear. Owing to the slipping of the belt which takes place, chiefly in the Stone system, but more or less in all systems, the belt becomes hot in working, and, in tropical countries especially, balata or rubber compound belts become sticky, and leather belts hard.

A good cotton belt, studded with copper rivets, to minimise the wear of slipping, is found to give as long a life as any.

The belt joint requires to be carefully made, it is necessary at times to take it apart quickly for tightening, and the " butt " joint thus is satisfactory if cut square, and properly made. Flush belt fasteners are also useful, and a number of good types are on the market.

Chain drives have been tried, and under some special circumstances, have done good work, but as a rule they are unsatisfactory and not to be recommended. The speed of a train is constantly being accelerated or decelerated suddenly, and as the inertia of the armature prevents it from responding at once, the result is disastrous to a positive drive. Even with belts the sudden slackening or "picking-up" of the wheels is responsible for many losses, the belt becoming suddenly slack and over-running the pulley.

Belt guards or catchers are very useful, as they prevent a belt which has broken from being lost on the road. Belts should be well stretched before being served out to examiners, etc., otherwise a new belt will stretch so much in a few miles as to be inoperative.

A good plan is to include in the length of belt, a small portion, say 6 inches, with fasteners complete, so that an examiner on finding the belt slack, can take the piece out, and thus shorten it, without undue delay.

Care should be taken to see that the belt joint cannot strike any portion of the bogie framing or headstock, should the belt "whip."

The flexible connections from the dynamo should be enclosed in metallic tubing, or firmly taped together to prevent injury from chafing or thrown up ballast. They should be properly marked to facilitate connecting up and to prevent making wrong connections.

Dynamo. The dynamo should be quite enclosed, and preferably water-tight, as it has to run under very unfavourable conditions, close to dust, etc., from the ballast, liable to be drenched with water thrown up from water troughs, or submerged during floods on the line, etc.

Oil has on most modern machines been discarded in favour of ball bearings. Although oil throwers were usually provided, they did not prevent the oil, especially when bearings were worn, from creeping on to the commutator and armature, and ultimately finding its way into the field windings.

Oil wells are also liable to become clogged, and unless great care is taken to empty them, before taking the dynamo down, oil is sure to get among the windings. Should oil be used, care should be taken that it is of such a nature, that it will not freeze in winter, or become too thin when running at high speeds in hot weather.

Ball bearings are now almost exclusively used, and when well charged with grease or vaseline, require no attention for long periods. It is necessary however that a good design of bearing is used, as should the races or balls, wear or break, or the spacing devices fall out, the dropping of the bearing would cause the armature to foul the pole pieces, and be destroyed.

Battery boxes. These should be strongly constructed of well-seasoned wood, and well supported. For a double battery it is usual to provide two boxes, one on either side of the underframe, as 24 cells together would necessitate a very large box, and the weight would be unevenly distributed. The number and size of boxes, however, is largely governed by the space available for them.

The whole front of the box should be removable, for ease in filling, but to allow for rapid inspection a portion of the top, about a foot deep, should drop down on hinges. Ample room should be allowed above the batteries for connecting up, as if room is too restricted here, accidental short-circuiting by the spanner is probable.

To prevent any movement of the cells in the battery box, clamping screws may be provided at each end, so that all may be pressed tightly together, suitable spacing boards being provided between each cell if required. It is far better to pack the cells so that they cannot move, than to depend upon elastic packing such as felt, etc., for absorbing shocks, as such packing soon becomes soaked with acid, and lowers the insulation resistance. The cells should not stand on sawdust or similar material, for the same reason. Drain holes should be provided in case of cells leaking, and every

effort made to keep the battery and box dry, as electrical leaks through damp boxes considerably reduce the capacity of the battery.

Batteries. The battery of cells, rendered necessary in all systems for maintaining the current at periods when the dynamo is inoperative, is perhaps the most important feature in the equipment, and that which will give trouble in service if not maintained in good order.

The bottom of a railway carriage cannot be considered an ideal position for a number of mechanically weak lead cells, and when to this fact is added the varying rates of charge and discharge, and the difficulty of seeing exactly what is going on, the life of train lighting cells must compare unfavourably with those in a stationary lighting plant.

Lights left on all night inadvertently, belts lost en route and not replaced quickly, or gravities and heights of electrolyte not corrected, speedily have a deteriorating effect, and a train lighting battery should be specially robust in order to cope with the work. The plates should be strong, with good substantial bus-bars and connecting lugs, adequate provision made to prevent splashing and loss of electrolyte, and facilities arranged for easy inspection.

Great improvements have been made recently in several types of batteries, but the lead cell (the most efficient electrically) is at a disadvantage when subjected to the shocks of shunting and the rough usage inseparable from railway work.

The positive plates are usually of Planté formation in which the pure lead plates are either chemically or electrically treated, until they become coated with lead peroxide, and the negatives of "box grid" or ordinary grid type, the active material being secured therein.

The "Faure" or pasted plates consist of grids usually made of hard lead, of which the positives are filled with a paste of red lead which on formation is converted into lead

peroxide. The grids are made of various forms, but are usually of such a section that the paste is keyed or dove-tailed in.

The usual form of failure of the Planté type, is that the plates, becoming more and more converted to peroxide, gradually disintegrate, while the pasted type suffers from the defect that the paste falls out, probably short circuiting the plates, but in any case reducing the capacity of the cell.

The containing vessels are usually of wood, teak for preference, as it is a good non-conductor. Oak, pine or deal are inadmissable as they do not resist the action of acid and quickly rot. The boxes should be fitted with lead linings with burnt joints, previously well covered with vaseline, so that any space between the lining and box is filled with the vaseline. Hard lead alloy sheet should be used as this is not so liable to be "pitted" by the acid and cause leaks. Several composition boxes are on the market under different trade names, the object of these is to dispense with the lead lining and its disadvantages.

The positive and negative plates are kept apart by separators, which may be either of ebonite, glass or wood. Both ebonite and glass are liable to be broken, but the wood separator supports the whole surface of the plate, and also absorbs the electrolyte, so that in the event of a leak the tendency is to keep the plates moist, so that they will not suffer so much injury as if allowed to become dry.

Ebonite sheets are provided between the edges of the sections and the lead linings, otherwise they would become short circuited.

The plates should rest upon a wooden, porcelain or glass cradle, to allow room for sediment to accumulate at the bottom of the boxes, without short circuiting the plates. The box lid is usually held down by brass bolts, a rubber ring making a tight joint, while the connecting bars or lugs, pass through rubber sockets in the lid, these precautions being necessary to prevent leakage by splashing.

Various remedies have been tried to counteract the trouble of splashing, but probably the best plan is to make the boxes as high as possible, so as to allow more room between the electrolyte and lid, and thus do without anti-splash devices altogether. Where this cannot be done, an extra thick or "double" lid appears to meet the case. If it were possible, it would be better to have no rubber or brass fittings on the cell at all.

A considerable improvement has been effected by the introduction of glass containing boxes. There are no ebonite sheets to perish or brass bolts to corrode, while the state of the cell can be seen at a glance. A most important duty in connection with the examination of a battery is that of checking its specific gravity. If properly done the electrical state of the cell can be ascertained at once, but unless reliable figures are obtained the operation is useless.

It is so often performed in a haphazard manner, that a word of warning is necessary. A good hydrometer with an open scale is required, and distilled or clean rain water only should be used for "topping up" purposes. The water used should be tested from time to time by simple re-agents to detect the presence of chlorine, nitrates, iron, or other dangerous impurities. Under no circumstances should acid of higher specific gravity than 1·400 be used for strengthening weak electrolyte.

In warm or tropical countries the temperature of the acid in the cell should be ascertained, and the specific gravity obtained, corrected for normal temperature, the hydrometer reading being increased by 1 for every 3° above 60°F.

The capacity of a cell is usually reckoned in ampere hours and in the case of pasted plates may be estimated at from ·3 to ·35 ampere hours per square inch of positive plate area, thus a 17 plate cell consisting of 8 positive and 9 negative plates, of say 7ins. × 5ins. will have a positive plate area of $7 \times 5 \times 8 = 280$ sq. inches. As both sides of the plate are effective this will equal $280 \times 2 = 560$ sq. inches, which multiplied by ·35 gives a capacity of 196 ampere hours. The

normal discharge is at either a 9 or 10 hours rating, so that 20 amperes could be continuously taken from such a cell for about 10 hours, by which time its voltage would probably have fallen to 1·8 volts, below which it is not advisable to discharge the cell or buckling and sulphation of the plates may occur.

The above rough rule does not apply to Planté formed plates, the capacity of which depends upon their thickness and degree of formation.

Charging should also be performed at a light rate at first, and continued for at least 24 hours, but in all cases the makers instructions should be worked to.

The acid used should be that known as " brimstone " acid, which is manufactured from sulphur. Acid made from pyrites, etc., is unsuitable, unless specially purified, for the purpose.

Both single and double batteries are used in train lighting equipments, the former chiefly for carriages having a fixed number of lights burning at one time. As the voltage of the battery when fully charged is greater than that of the lamps, a resistance is inserted in the lamp circuit to reduce the voltage. As the same number of lamps are always used together, the value of this resistance can thus be precisely determined and set. Should it be necessary for the carriage to require half lights at times, the lamps are arranged in two circuits, half and full lights, each with its resistance.

On carriages, however, with individual lamps which can be switched on or off at will by passengers, as in sleeping cars, etc., this arrangement would not be practicable, as each lamp switched on or off would diminish or increase the illumination of the others.

Some systems are, however, capable of affording the necessary lamp regulation with a single battery by using lamp regulating apparatus in conjunction with it, but where no separate regulating device is employed, a double battery is usually equipped, one battery being charged while the other

is connected with the lamps through a resistance. Arrangements must be made for changing the batteries over periodically, so that the discharging one receives a charge and *vice versa*. This is usually effected by automatic means, and the arrangement of variable speed dynamo, "cut-in" switch, and double battery with lamp resistance, forms the simplest combination for train lighting.

The lamps should be controlled within 2½% of their rated voltage, or the variation of illumination becomes noticeable, and as the voltage of a battery of 12 cells may vary between 21½ volts when discharged and 33 volts when fully charged, the efforts of inventors have been directed towards obtaining closer control. The various automatic regulating devices illustrated represent some of the more successful types in general use. Many of them fulfil a number of functions, not only controlling the lamp voltage within close limits, irrespective of the state of charge of the batteries or number of lamps in use; but they also control the field current of the dynamo, so that it responds to the requirements of the battery, allowing the full output to a discharged battery, while gradually reducing and finally stopping the current when it is charged. The regulator of one system guards against the abuse of the lights by switching them off when the battery has reached a certain limit of discharge, and refusing current to the lamps again, until the dynamo commences to generate.

Some systems provide for the batteries being charged at constant voltage, while others adopt a constant current principle. If a constant voltage of 2·5 volts is adopted the current must fall off as charging proceeds, and reaches the minimum when the battery is charged. Objection has been made that the small final current is insufficient to promote the necessary circulation of the electrolyte by "gassing," and that consequently different densities of the liquid may exist—an undesirable feature in a battery.

If the constant current principle is used, however, the voltage must be gradually increased as the battery is charged, and probably too much "gassing" produced. This is

injurious as it causes particles of the active material to be shed from the plates, not only decreasing their capacity, but forming an abnormal quantity of sediment.

Between the extremes of constant voltage and constant current variations may exist, as for instance, constant current to the battery independent of the lamp load.

The automatic "cut-in" or dynamo switch is a simple device. If electrical it usually takes the form of an electro-magnet energised by the dynamo current, so that on the voltage rising to that of the battery, an armature is attracted and the connection made.

Mechanical switches usually depend upon centrifugal force; on the dynamo attaining a certain speed, revolving weights, by their movement close the switch. As the operation of the mechanical switch, however, does not depend upon any electrical effect, it is possible for the switch to close or open at a dynamo voltage which does not correspond with the battery voltage, thus burning the contacts of the switch. Auxiliary carbon contacts should therefore be provided at which the arc is broken.

The "cut-in" switch, regulating device, etc., are sometimes placed under the carriage, although, where room can be found for them, they are much better inside. If they are incorporated with the lighting switches they should be in a separate portion of the box, not accessible to the guard, unless he is competent to deal with them.

Apparatus which depends upon solenoidal action should not be placed at the end of a carriage, if possible, as considerable "hunting" is often caused by vibration.

The circuit should be properly protected by fuses, as in railway work various events may arise to cause a short circuit, the equipment being practically at the mercy of non-electricians, carriage cleaners, station staff, etc. In any case a fuse should be inserted in the armature circuit, or the accidental or deliberate manipulation of the automatic "cut-in" switch will almost certainly burn out the armature,

owing to its low resistance and inability to start when the belt is on.

Wiring. Owing to the low voltages used in train lighting, due to the necessity of keeping the number of cells low, comparatively heavy currents are necessary, the output of the larger machines reaching 100 amperes or more. Fireproof cables should always be installed, as although it is practically impossible to maintain an arc at the low voltage used, much alarming smoke and charring can take place if a short circuit develops in the mains.

Every care should be taken in wiring the interior of the carriage, and the leads kept well away from any fittings likely to be often renewed by the carriage repairers, or they will probably be damaged.

The wiring should be carried out to a diagram which, if filed for reference, will save much subsequent searching for the wires. Another rule which should be adhered to is to use distinctive coverings, say, red-covered wire for positive and black for negative mains and leads, otherwise wrong connections are liable to be made.

Lamp holders are a fruitful source of short circuits, due to chafing, etc., and switches with fuses incorporated are very convenient for locating these faults.

The fittings should be of a type which a passenger cannot tamper with ; lamps in enclosed and locked fittings ; and switches with covers that can only be removed by a special tool.

In tropical countries fans are usually installed, and these also should be fused, while their regulators, if any, should be placed in such a position that they cannot scorch any woodwork, etc. Fans should have their bearings kept in good order, otherwise they will absorb an excessive current.

The underframe wiring should be carefully carried out ; under favourable circumstances ordinary cleats to the underside of floor are sufficient, but where the wiring passes under lavatories, etc., proper casing, or even conduit is desirable.

SYSTEMS OF TRAIN LIGHTING.

BROWN BOVERI SYSTEM.

The above system, the invention of Messrs. Brown, Boveri & Co., of Baden, although not in use in England is extensively used in Germany and Switzerland.

It consists of a dynamo, regulating apparatus and single battery. The dynamo, which is suspended in the usual manner, and driven from one of the axles, is a shunt wound machine of ordinary type. The change of polarity, due to the change of direction of rotation, is brought about in the usual way by rotating the brush holder or alternatively by raising the brushes and replacing them automatically with a new set in the correct position for collection.

The regulating apparatus comprises several parts, all assembled in one box. The latter consists of a cast iron plate, on which the various apparatus are mounted, and a sheet iron cover.

The duty of the regulating apparatus is to automatically fulfil the following working conditions :—

1. To switch the dynamo in and out of circuit.
2. To limit the current to a certain value, according to the type of battery used, and to decrease it to a minimum whenever the battery becomes fully charged.
3. To keep the voltage at lamps constant, independent of the rise or fall of battery voltage or number of lamps in circuit.

A diagram of the apparatus is shown in Fig. 2.

The essential parts are the "cut-in" switch C and regulating motor R.

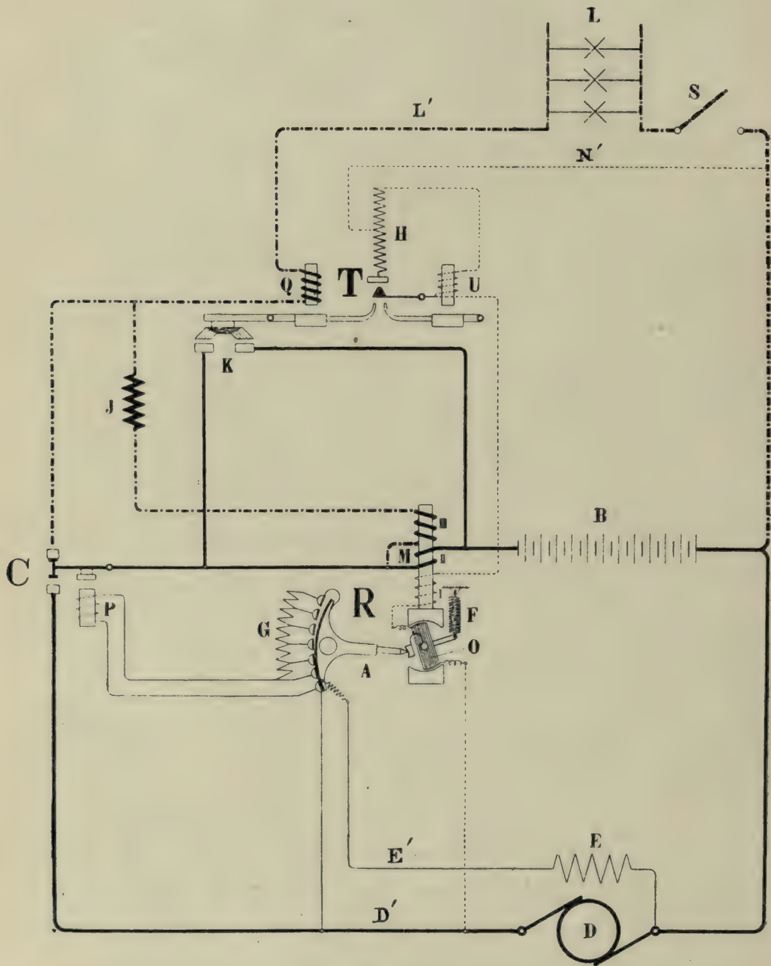


Fig. 2.

The regulator consists of a moving coil O which is placed between the field poles of an electro-magnet, having a shunt

winding M and series windings M2 and M3. The moving coil is capable of a partial rotation and actuates a sector-shaped contactor A which rolls over a curved path composed of silver contact blocks. The sections of the field resistance G are connected to these contacts. A spring F controls the movement of coil O and exercises an approximately constant tension upon it.

The winding of the moving coil is connected in series with magnet winding M1, overcharge relay U and resistance H, all being connected across the dynamo terminals.

The first two contacts of resistance G are connected to magnet winding P of the "cut-in" switch C. As soon as the dynamo reaches the speed at which the voltage exceeds the predetermined amount the moving coil actuates the contactor A so that it rolls away from the contacts, short circuiting magnet P which is consequently energised and closes the switch C, connecting the dynamo to the battery, and at the same time disconnecting the battery from the lamps (at C). The lamp current has therefore to pass through series coil M3 and resistance J. As the speed of the dynamo increases the voltage is kept constant by the introduction of resistance, in steps, by the regulator.

If the lamps are "on" the switch K is closed, short circuiting coil M2, when they are switched "off" K opens, putting coil M2 into circuit.

The battery charging current passes through M2 and assists the coil M1 in moving the regulator. The result is that when the dynamo is running, and the lamps are "off" the voltage necessary to actuate the moving coil O will be low, although the charging current is high. The reverse is the case when the lamps are switched on. This is due to the increasing back E.M.F. of the battery as it becomes charged, with a consequent fall of current, requiring a higher dynamo voltage through the regulator windings to move coil O. The charging continues until the armature of the

magnet U is attracted, partially short circuiting the resistance H. This reduces the dynamo output to a minimum by causing the sector A to roll further over the resistance contacts.

If the lamps are not switched on, current will flow through resistance J and magnet Q, closing switch K, and short circuiting the battery winding M2. The lamp current will then flow through the winding M3 acting in opposition to the winding M1, thus as the lamp current becomes greater, the dynamo voltage must rise higher to balance the force of the control spring F, while with the larger lamp current the resistance drop in J becomes greater, so that the lamp voltage remains constant.

IMPROVED DALZIEL.

This lighting system employs a dynamo which, with the aid of a small exciter geared to it, has inherent self-regulating properties, and gives a constant voltage independently of load or speed.

Fig. 3 shews the diagram of connections, and it will be seen that the field circuit of the dynamo includes an exciter which has two poles in series, both of which are in parallel with the exciter arm, *i.e.* the exciter arm carries the excess of flux produced by the saturated pole.

Complete diagram of connections of D.C.V. Train Lighting Equipment shewing only One Light's circuit and One 3 Point Switch.

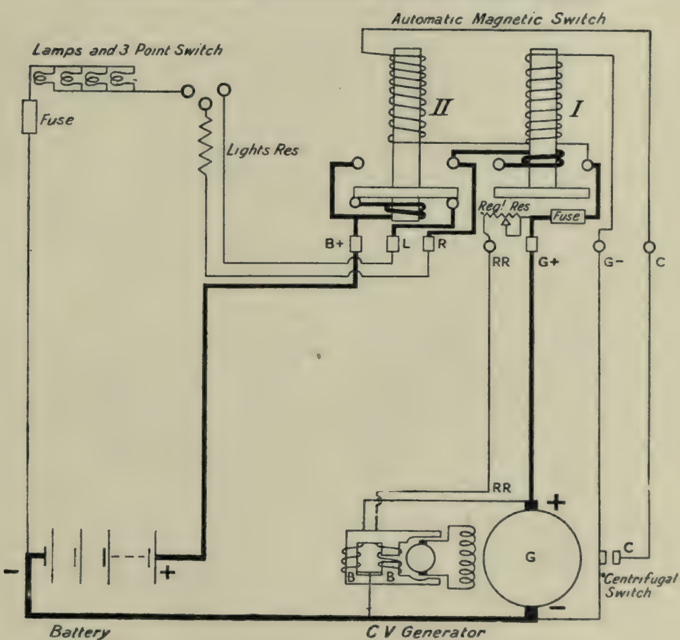


Diagram corresponds to standing train _ Lights off.

IMPROVED DALZIEL SYSTEM.

Fig. 3.

One of these poles is of small cross section and is very highly saturated, while the other is of considerably larger cross section, and has in its path an air gap of considerable length.

Both of these poles are excited either from the dynamo brushes, or from the point at which constant voltage is required, so that the magnetomotive force of each will vary in direct proportion to the pressure to be controlled.

The flux in the saturated pole, however, will reach, or tend to reach, its full value when supplied with approximately only one-tenth of its normal magnetomotive force. After this point has been passed the flux will remain practically constant regardless of increase of magnetomotive force, as the degree of saturation is extremely high.

The flux in the pole of large section will vary in almost direct proportion with the M. M. F. or in other words, with the pressure from which its excitation is derived.

As these poles are in series there can be only one value of excitation at which no flux is carried by the exciter armature.

This value of excitation is made to correspond to a value of the voltage of the main dynamo very little in excess of the prearranged constant voltage.

When giving full load at the lowest cutting-in speed of the main dynamo, the exciter armature is designed to give the necessary excitation with only a very small percentage of the flux in the saturated pole passing through it.

The field winding of the main dynamo is connected directly across the exciter armature.

It will be seen therefore, that as only a very small percentage of the flux in the saturated pole is used for the maximum dynamo excitation, the voltage rise is limited to this very small amount, through a very large speed range.

The degree of saturation in the saturated pole is such, that while the machine is standing, the residual flux in that

pole, and passing through the exciter armature, is probably in excess by a large amount of the flux required when running. This will be evident when the smallness of this latter amount is considered with the fact that practically none of the residual flux will pass through the air gap of the unsaturated pole. This being the case the main dynamo has no alternative but to build up current, providing the main shunt circuit is complete.

It will be clear that although at very low speeds the flux through the exciter armature is very high, the product of this flux and the speed is definitely limited, and never can be sufficiently great to saturate the main dynamo field.

No pole changer is required with this system for the following reason :—When the dynamo comes to rest and is reversed the residual flux in the exciter field circuit remains in the same direction—the current in the exciter armature is therefore reversed. The main dynamo field winding being connected directly across the exciter armature is also reversed, the combination of this reversal and the reversal of rotation giving a polarity to the main dynamo current in the original direction.

The dynamo is connected to the battery at the correct voltage by means of the solenoid switch I., provided with series and shunt windings, but the connection instead of being direct, is through the lamp resistance and lamp switch. When the latter is closed the current flows from G, through I., terminal R, lamp resistance, lamp switch, terminal L, switch II., and through its series coil to the positive of battery.

As the speed and voltage of the dynamo increases, it takes over the lamp current, and the current in the series coil of switch II. is reduced to zero, consequently as soon as the centrifugal switch C operates to complete the circuit of the shunt winding, the switch II. closes, connecting the dynamo direct to the battery, but leaving the lamp resistance between the lamps and dynamo, the reverse taking place when the train slows down, and the dynamo speed falls.

A lamp resistance is employed with each lamp or group of lamps supplied with a separate switch, in order to absorb the difference between dynamo and lamp voltage. The resistance is inserted in switching in.

The apparatus is made by Dalziels Constant Voltage Patents Ld., of London, S.W.

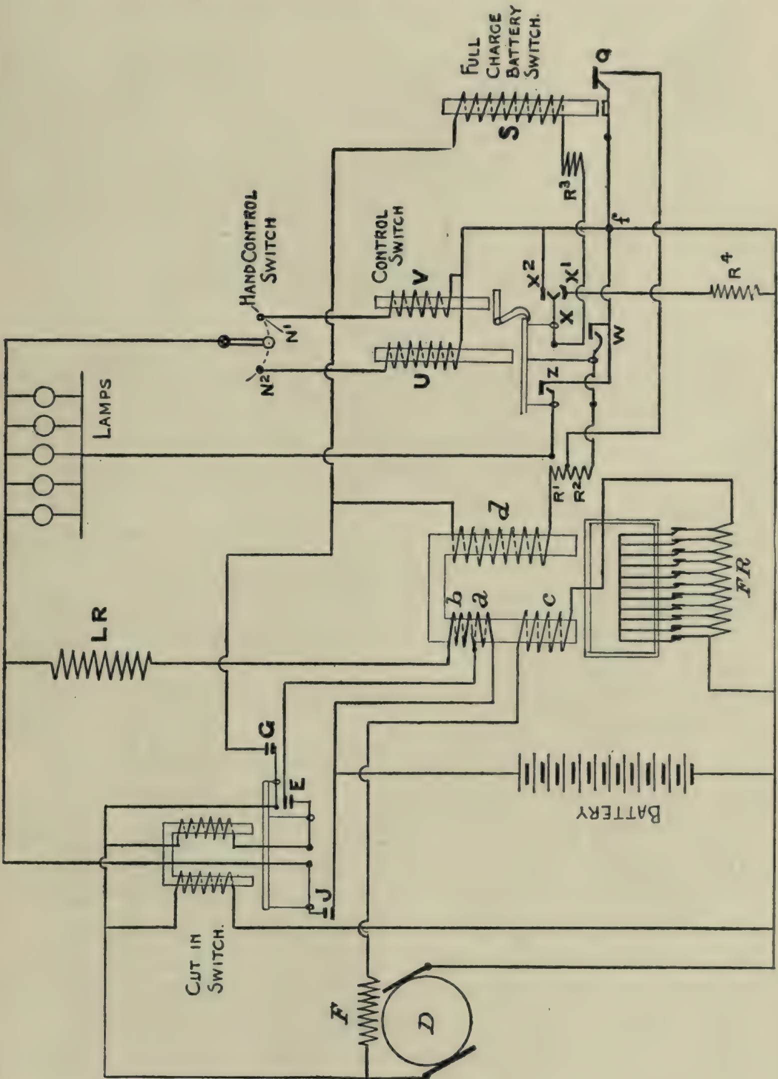
EARLE'S SYSTEM.

This system, the invention of the Carriage Superintendent of the London & North Western Railway, introduces a novel variable resistance.

Fig. 4 is a diagram of the arrangement of wiring, etc., and the operation is as follows :—The automatic shunt field resistance regulator FR is employed in conjunction with the field winding F of the dynamo D, and comprises an electro-magnet core on which are wound four coils, *a*, *b*, *c* and *d*. *a* is the battery main series coil, *b* the lamp main series coil wound to oppose magnetically the core *a*, *c* is a coil inserted in the shunt field circuit and also wound to oppose coil *a*, and *d* a shunt regulating coil wound to assist the coil *a*. The resultant magnetic effect of the windings *a* and *c*, or *a*, *b* and *c*, or *c* and *d*, or *a*, *b*, *c* and *d* influence in a different way the armature of the regulator. The armature carries a cross-bar which operates successively electrically connected spring blade contacts for varying the resistance of the field circuit. The movable contacts are arranged to bear upon fixed contacts, both being of carbon. By specially shaping the cross-bar the contacts are lifted in succession so that the resistance is varied very gradually.

In addition to this regulator four other switches are shown, the usual " cut-in " dynamo switch, a magnetic switch for controlling the lighting current, a full charge battery switch, and a control switch. The " cut-in " switch has a shunt winding connected across the dynamo, and a series winding connected at one end to the dynamo and at the other to a movable contact, which is arranged to be operated by the magnet armature. This armature also makes the other two contacts shown.

The magnetic controlling switch comprises two electro-magnets one of which controls an armature while the other controls a pivoted catch, which holds the armature up.



EARLE'S SYSTEM. Fig. 4.

The three movable contacts are arranged to be operated by the armature.

The full charge battery switch also comprises an electro-magnet arranged to make the contact Q.

The control switch is operated by hand and comprises a spring switch arm, which can be moved from a mid position and pressed on either of the contacts shown and then released.

The regulating switch, working in conjunction with the other switches controls the output of the dynamo under different conditions, the chief of which are as follows :—

a. Dynamo running with lights off and cells being charged. When the dynamo commences to generate the "cut-in" switch operates at the prearranged voltage and closes the contacts at E and G while opening the contacts at J. Current now passes to the battery, through contact E and the main series coil *a* of the regulating switch, which, in consequence, raises its armature and commences to insert the resistance FR in the dynamo field. The shunt current also passes through the coil *c* but in a direction to oppose *a*. Therefore, as the resistance FR is gradually inserted, by the raising of the necessary contacts, the current in the field is reduced, and the main series coil *a* is able to exert more power on the armature working the contacts, and thus the battery is charged at a suitable rate, irrespective of the speed of the dynamo.

b. Dynamo running and charging with lights on. As before, the cut in switch operates to close contacts E and G and the current divides, one part going to the battery and the remainder through coil *b* to the lamps through the lamp resistance LR. A smaller portion of the dynamo current passes through contacts G and divides, some passes through coil *d*, resistances R1, R2 and contacts W., the remainder through the full charge battery switch coil resistance R3 and contacts X. The current to the battery passes through the series coil *a*, and that to the lamps through the lamp series coil *b*, which is in opposition to *a*, the circuit from the lamps

being completed by way of contacts Z back to the dynamo. The coil *b* thus helps the coil *c* in opposing coil *a*, so that a suitable resistance is kept in the field, it being understood that as the load increases the field resistance decreases, due to the action of coil *b*.

c. Dynamo running with lights off and battery fully charged. When the battery voltage reaches a predetermined value, sufficient current passes by way of contact G, coil o′ full charge battery switch, and resistance R3 to contacts X, and thence by resistance R4 (which regulates the voltage at which the battery switch will operate) to attract the armature of the switch and close contact Q. This contact being closed completes the circuit of the regulating shunt coil *d* of the field regulator from a point between the resistances R1 and R2 to a point *f* connected to the main negative, and thus short circuits the resistance R3.

The coil *d* thus assists coil *a* to oppose coil *c*, and the three windings are so proportioned that suitable resistance is inserted in the field of the dynamo.

d. When the dynamo is running with lights on and cells fully charged the conditions are as above, until the arm of the lamp control switch is pressed against the "on" position contact N2, which, as in case *b*, causes current to flow through coil U of control switch, thus attracting the armature, bringing into engagement contacts W and Z and interrupting the circuit of the coil of battery charge switch at X1 although closing it again at contact X2. Current now passes through coil S of battery switch, resistance R3 and contacts X2 omitting the resistance R4, so that the battery switch is again set to operate at a lower voltage than in cases *a* and *c*. Assuming contacts Q to be closed and the current from the dynamo passing through the series coil *b* to the lamps and contacts Z, the result is that coils *b* and *c* assist each other, while *a* and *d* oppose them, and the joint effect is to introduce suitable resistance into the field circuit for regulating the dynamo output, and for maintaining constant voltage at the lamps.

In cases *a* and *c* when the arm N of the lamp switch is pressed against the "off" contact N1, current passes through coil V, operating the catch of the armature shown, and opening circuits at contacts W, X and Z and closing circuits at contacts X and X1.

This system is still in its infancy, and is fitted to several carriages for experimental use.

E. S. B. SYSTEM.

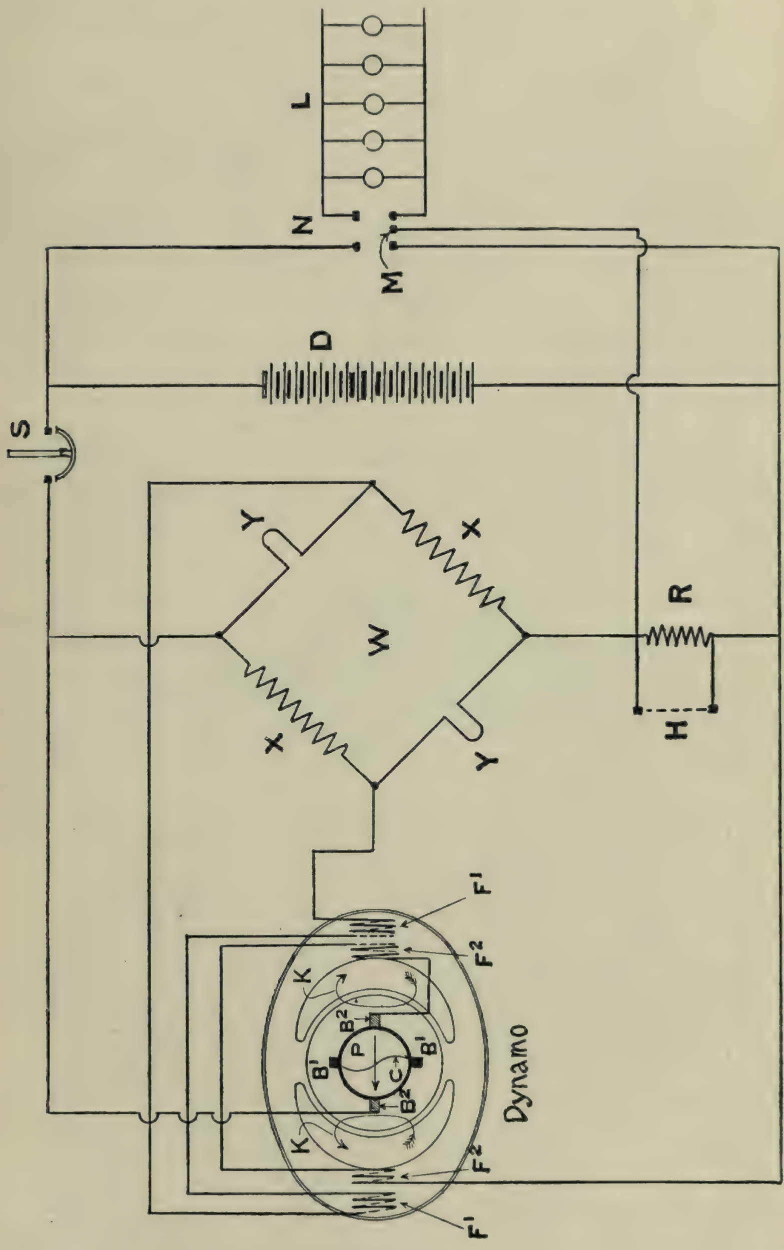
This system, which has been developed by the Electric Storage Battery Co., of Philadelphia, is in use on various American railways.

The dynamo is of the Rosenberg type (described in Mather & Platt's system) but re-designed by the Electric Storage Battery Co. to operate in connection with its constant voltage regulator.

Referring to Fig. 5 current in the primary field winding F^1 produces a small primary field flux, represented by the arrow P, which induces a small electromotive force between the short circuited brushes B^1 and a flow of current through the short circuit connection C.

This current flowing through the armature winding produces by armature reaction the secondary or principal field flux, which does not pass through the frame of the machine, but is confined to the heavy pole shoes and the armature, as shown by the arrows K.

This latter flux produces the electromotive force at the principal brushes B^2, which are connected to the external circuit, a series field winding F^2 in this circuit serving to balance the armature reaction due to the load. Like the Mather & Platt dynamo it generates the same polarity with either direction of rotation, thus requiring no pole changer.



E. S. B. SYSTEM. Fig. 5.

The primary field winding F^1 is connected across opposite junction points of the Wheatstone bridge W, the other two junction points being connected respectively to the positive and negative terminals of the machine. This bridge is designed to give the constant voltage characteristics above mentioned. It includes fixed resistances X in opposite branches and iron wire ballasts Y in the other two branches. The latter, on account of their high temperature co-efficient, have a practically constant current characteristic under operating conditions. This combination of circuits produces a field excitation continually diminishing with increase of speed, with a resulting steady voltage.

An automatic "cut-in" switch S connects the dynamo to the battery D when the voltage of the former is slightly above that of the latter, and opens when the output of the dynamo drops to zero. The knife switch N connects the lamp circuit L to the battery.

The voltage of the dynamo is fixed at a point slightly above the floating voltage of the cells to ensure that the battery is always fully charged. The difference between this voltage and that of the battery on discharge is considered so small and the change from one to the other so gradual that no special regulator for the lamp voltage is provided.

Should it ever be found necessary to give the battery a high voltage charge, this may be done during a daylight run by means of the fixed resistance R, normally short circuited by the switch H, and also by the clip M on the main lamp switch. When both these switches are open the voltage of the dynamo is raised by an amount determined by the value of the resistance R. Whenever lights are required the closing of the lamp switch N short circuits the resistance R, reducing the voltage to normal and eliminating the possibility of excessive voltage at the lamps.

LEEDS FORGE SYSTEM.

This system, which is put on the market by the Leeds Forge Co., Ld., of Leeds, depends for its operation upon the automatic regulating properties of the dynamo itself, and may be generally described as giving constant current. The usual "cut-in" and "cut-out" switch for connecting and disconnecting the dynamo with the battery is provided, and also a lamp switch which regulates the voltage to the lamps irrespective of the battery voltage.

The dynamo is of novel construction. The armature, fields and poles are of the usual type, but the armature with its commutator is mounted upon a sleeve, free upon the main shaft as shewn in Fig. 6. The armature is driven by a pin B, which works in the spiral groove or cam A cut in the sleeve attached to the armature.

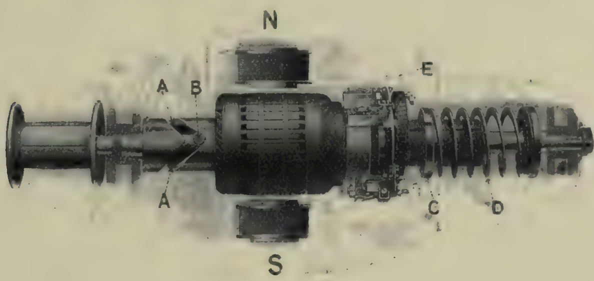


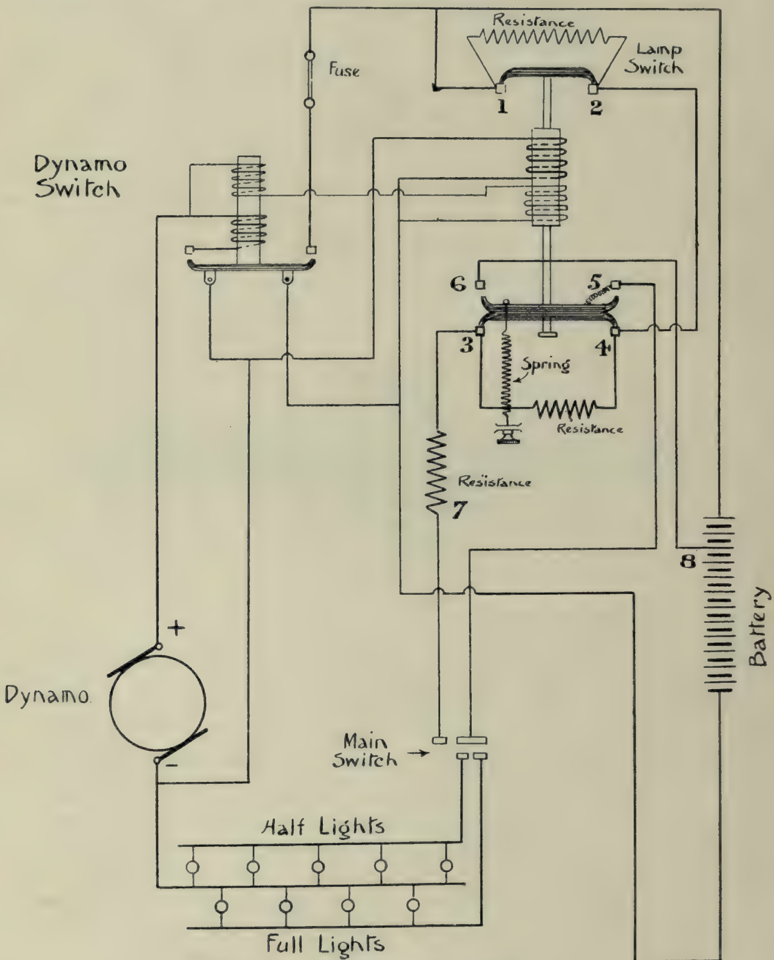
Fig. 6

When the shaft is rotating, either in one direction or the other, the pin bears against the side of the slot, and so causes the armature to rotate. The power to rotate the dynamo shaft cannot alter as the pin B has a tendency to ride along the groove, and as the shaft is fixed in its bearings, the armature is caused to be pushed out of the influence of the field magnet poles NS.

This is effected against the force of the regulating spring D. As the speed increases the armature is moved farther out of the field and *vice versa*. To change the output the force of the spring D can be regulated by the nut C.

The cam groove A being cut in both directions the action is, therefore, exactly the same in whichever direction the dynamo runs.

The brushes are arranged to move round by the usual device of a rotating brush holder, but, by the addition of a tapered stop on the dynamo frame, the brush rocker which



LEEDS FORGE SYSTEM.
Fig. 7.

slides along the shaft with the armature, is enabled to give the correct " lead " for any armature speed, thus ensuring sparkless running

The automatic " cut-in " switch is of the solenoidal type, with shunt and series winding.

For regulating the voltage to the lamps, between full charge and discharge voltage of the battery, a lamp switch is provided, which brings either 10 or 12 cells into circuit: 10 cells at full charge voltage of say 2·4 volts, or 12 cells at 2·0 volts approximating to the lamp voltage.

The arrangement of connections is shown in Fig. 7, the operation being as follows :—

Assuming the dynamo is stopped, the "cut in" switch will be open, and any lamps alight receive current direct from the battery, the resistance 7—1 being short circuited. When the dynamo starts running and reaches the necessary voltage the " cut-in " switch closes and the dynamo commences to feed the lamps. As soon as the voltage rises sufficiently high to charge the battery, the lamp switch rises owing to the battery current flowing through the series coil, in addition to the dynamo current through the shunt coil. The first movement lifts the top switch bar and inserts resistance at 1—2, and as the current to the battery becomes stronger the force of the spring is overcome, the lower switch bar is tilted across 3—5, thus inserting another resistance in series with the first. On the current further increasing the spring is overcome, and the switch bar tilted across 6—5 inserting the final resistance 3—7 and connecting the lamps across the cells. This action takes place between " cut-in " speed and the normal dynamo speed.

When the normal number of lamps are in circuit no current flows in balance wire 7—8. Switching lamps off only causes the balance of current to flow through 7—8 and does not appreciably alter the voltage at the lamps.

LEITNER SYSTEM.

The above system is the property under license, of the Leitner Electrical Co., of Woking, and is in fairly extensive use, particularly on the Great Western Railway.

The equipment comprises the following principal parts: dynamo, automatic cut-in switch, and battery of 12 cells.

The dynamo, which has inherent properties of self-regulation, is well built and fitted with ball bearings, the polarity of the current being rendered constant by the usual device of a rotating brush holder, which is automatically carried round to correct positions, so that the brushes obtain proper lead.

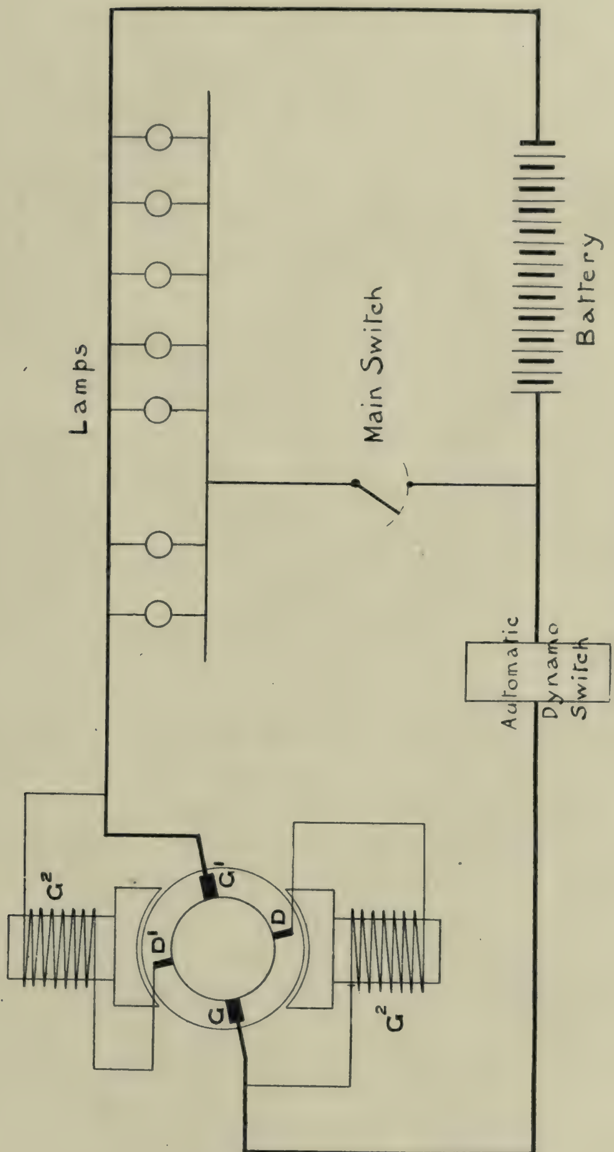
The automatic regulation of the dynamo is effected by the employment of subsidiary brushes, and their effect will be understood by a reference to Fig. 8 which shows a bi-polar dynamo (although four-pole machines are usually fitted).

G and G^1 are respectively the main positive and negative brushes. G^2 is an ordinary shunt winding across the main brushes G and G^1, but instead of being continuous, as would be the case in an ordinary shunt machine, the positive and negative halves are connected respectively to the subsidiary brushes D and D^1.

If the direction of rotation of the dynamo is as shown by the arrow, a potential difference at starting is created between D^1 and D, the former being positive and the latter negative. This voltage, being in series with the field G 2, assists rapid excitation.

But as the current flowing out at G and G 1 increases, the armature flux increasingly distorts the field flux, in the direction of rotation, and in consequence the voltage between D^1 and D is first reduced to zero, and then reversed in sign, D^1 becoming negative and D positive.

This voltage, which is increased by the load and speed, opposes that of the field, so that the latter is weakened in proportion to the speed by counter EMF.



LEITNER SYSTEM.
Fig. 8.

The diagram shows the essential parts of the equipment, the self-regulating feature of the dynamo keeping the battery voltage approximately constant.

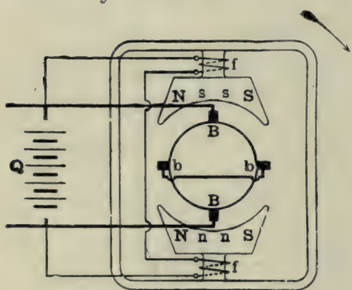
If a very exact degree of regulation of lamp voltage or battery charging current is desired, the Leitner Co. can provide a regulator which is capable of performing these functions within exceedingly close limits, in fact any desired degree of refinement can be easily provided to meet exceptional working conditions.

MATHER & PLATT.

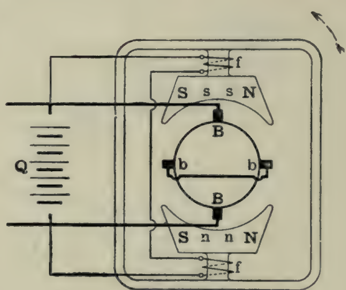
This system employs a dynamo which has inherent properties of self-regulation, and it effects this automatically without any external regulating devices whatever. In addition the polarity of the current is constant, and independent of the direction of rotation of the armature, thus dispensing with pole changing apparatus. In common with other systems a switch has to be provided for automatically connecting and disconnecting the dynamo and battery when the train starts or comes to rest. A regulator is included in the shunt field of the dynamo so that the output can be adjusted to any desired amount.

Before describing the operation of the system, the main features of the dynamo may be noted.

The arrangement of the dynamo windings are shown below and a reference to this figure will serve to explain the theory of the machine.



A



B

The dynamo consists of an armature and field magnets as in an ordinary generator, except that the pole limbs and yoke are of much smaller cross section than usual. The number of poles may be varied according to the capacity of the machine, but for train lighting purposes a two pole construction is usually employed.

The armature and commutator are precisely similar to those of an ordinary bi-polar machine, the windings being of the drum type and connected to the commutator in the usual way. The brushes *bb*, however, which in a normal machine would supply current to the external circuit, are short circuited, and are called " aid " brushes.

A second pair of brushes is placed at right angles to the first pair and these constitute the main working brushes from which the current to the external circuit is led. The field magnets are shunt wound. These windings *ff* establish a flux in the field magnets and armature, passing vertically through the latter as indicated by the letters *ss*, *nn*. The rotation of the armature in this field induces in its conductors, currents which circulate through the aid brushes *bb*.

Obviously a very small flux is sufficient to produce a large short circuit or aid current and therefore the dimensions of the shunt windings *ff* are relatively small.

The currents flowing in the armature, short circuited by the brushes *bb*, produce a flux through the armature at right angles to the primary flux.

This flux circulates round the pole pieces and armature as indicated by the letters NN, SS and does not traverse either the pole limbs or yoke which carry the primary flux. The rotation of the armature in this secondary flux produces a difference of potential between the brushes BB and sends current into the external circuit.

If for the sake of clearness the currents flowing in the armature be considered as existing in two independent windings, it will be observed that whereas the currents

flowing through the aid brushes *bb* produce a flux at right angles to the primary flux, and therefore producing no effect on this latter flux as regards magnitude, the currents flowing through the main brushes BB produce a flux exactly opposed to the primary flux, and accordingly diminishing it in exact proportion to the strength of the current in the external circuit.

It follows therefore that for a certain value of the external current, the ampere turns of the armature will exactly correspond to the ampere turns of the primary exciting winding, and being equal and opposite, the resultant flux would be zero. As without a primary flux the dynamo would cease to generate current, it is clear that the limiting value to the external current, which the dynamo can produce is that current which makes the armature ampere-turns equivalent to the field ampere-turns. Further, as a very small excess of field ampere-turns over armature ampere-turns is necessary to produce the current in the aid brushes which sets up the working field a very small diminuition in the current in the external circuit is sufficient to produce this working flux. A numerical calculation will make this evident.

At normal speed an aid current equal to about 40 per cent. of the external current is sufficient to produce the working flux, and for this current an excess of field ampere-turns over armature ampere-turns of 10 per cent. only is required. Now if the speed increases to four times the normal, or even to an infinite value, the current cannot increase by more than 10 per cent. for a 10 per cent. increase would entirely neutralize the primary flux. On the other hand if the speed falls to say 70 per cent. of the normal value, the current would fall, but should it fall by even as little as 10 per cent. of its normal value, the primary flux would immediately be doubled, producing a rise in the aid current of about 40 per cent. and increasing the horizontal armature flux sufficiently to compensate almost exactly for the change in speed.

The fact that the compensation for speed variation depends on the differential action of two practically equal quantities is the principal reason for the extremely exact automatic regulation which is obtained with this dynamo.

The effect of reversing the direction of rotation of the dynamo is shown in the figure B. Since the current in the primary exciting windings remains unchanged, the direction of the aid current is reversed. The horizontal armature flux produced by the aid current is therefore also reversed, and this reversal, in conjunction with the change in direction of rotation of the armature, causes the direction of the current in the external circuits to be the same as before.

At low speeds the aid current rises rapidly as the speed decreases, and in order to avoid the possibility of the aid current reaching an excessive value, it is found advisable to let the iron of the magnet yoke or core become saturated when the flux reaches a value corresponding to the maximum safe-aid current, then if the speed falls below that corresponding to this point the aid current will decrease, until finally the voltage of the machine will fall below that of the battery, when the dynamo " cut-out " switch will operate.

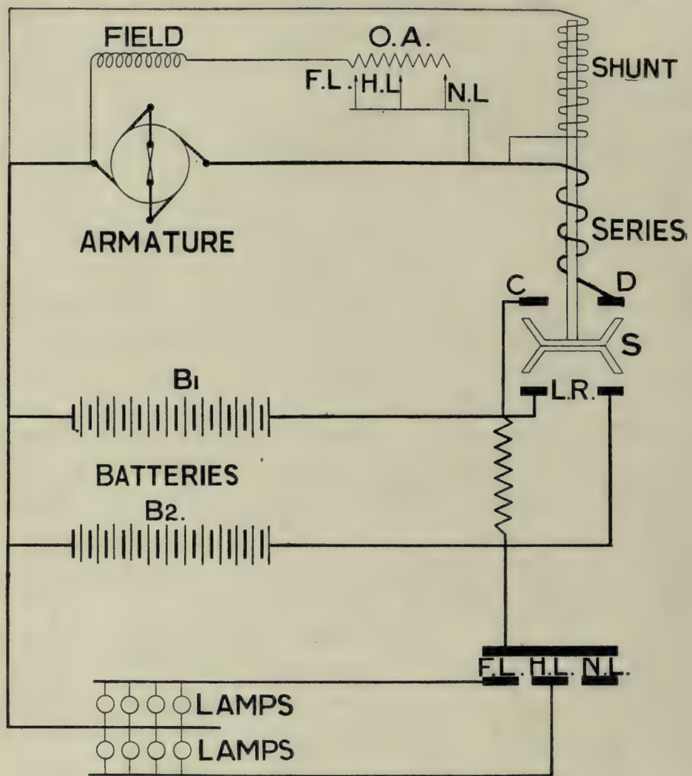
The commutation of the machine is practically perfect owing to the favourable conditions. The aid brushes work in a neutral zone, there is no difference of potential between them as they are short circuited, and the current flowing between the brushes is quite small except at low speeds. The main brushes work in a field particularly favourable to good commutation.

The reaction of the secondary on the primary flux produces a resultant flux which is inclined at a slight angle opposite to the rotation of the armature's rotation, this being equivalent to giving the brushes " lead "

Fig. 9 shows how the dynamo, batteries and lamps are connected together.

When the train is at rest or moving very slowly the solenoid " cut-out " switch is in its lower position, and the

two batteries B1, B2 then feed the lights in parallel through the main switch, under these conditions the switch is disconnected from the lighting circuit at the point D. As the speed of the train increases the voltage of the dynamo rises, causing the current to flow through the shunt winding of



MATHER & PLATT SYSTEM.

Fig. 9.

the "cut-out" switch S. When the voltage of the dynamo is slightly higher than that of the battery, the plunger of the solenoid "cut out" is pulled up closing the circuit at CD and breaking the circuit at LR. This voltage is reached at a speed of about 8 miles per hour. At the moment of

"cutting in" the dynamo supplies only a small current thus preventing any burning of the switch contacts taking place.

On the speed of the train decreasing below 8 miles per hour, the current which the dynamo generates falls rapidly until at a speed of about 5 miles per hour it reaches zero, and then tends to reverse. Immediately a small reverse current passes through the dynamo, the series winding (the current through which is normally assisting the shunt and increasing the contact pressure) acts in opposition to the shunt winding, thereby demagnetising the plunger and causing it to fall. The dynamo is then cut out of circuit, and at the same moment the lamp resistance LR is short circuited and both batteries are connected directly to the lamp circuit.

The dynamo output is adjusted by means of a suitable resistance OA in the shunt circuit which is capable of close adjustment, and portions of which are brought into circuit according to the "Full-light" "Half-light" or "No light" positions of the main lighting switch.

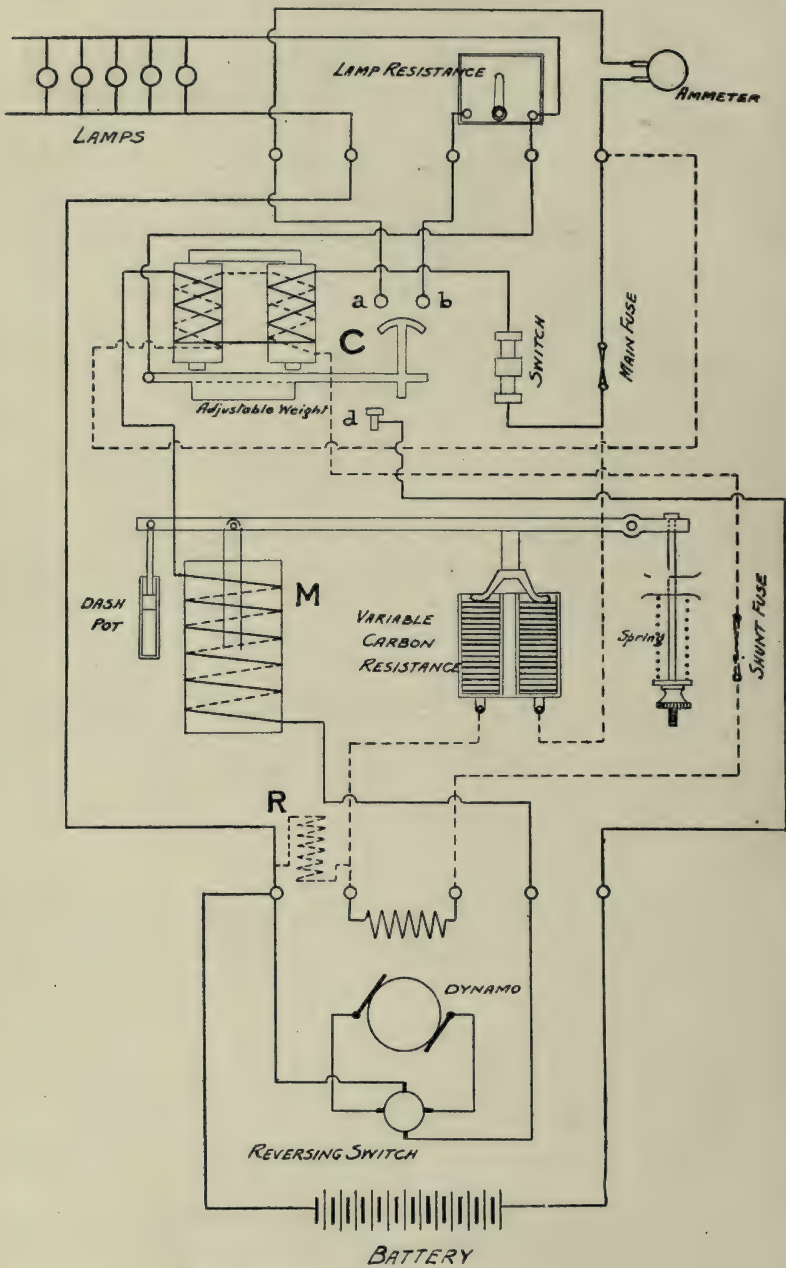
A lamp resistance LR is also provided which inserts resistance according to the main switch positions.

MOSCOWITZ SYSTEM.

This system, which is used to some extent in America, consists of a dynamo and a variable field resistance, by means of which regulation is effected.

The dynamo is a shunt wound machine of ordinary construction, without special features, save for a reversing switch on the end of the armature shaft for reversing the connections according to the direction of travel, and thus maintaining a constant direction of the current in the external circuit.

In parallel with the shunt circuit is the variable resistance consisting of a pile of carbon plates, which are capable of being



MOSCOWITZ SYSTEM. Fig. 10.

pressed tightly or loosely together, thus varying their resistance. This is effected by a lever operated by an electromagnet as shown in Fig. 10. The pull of the electro-magnet M can be varied by adjusting the spring S, and consequently the output suited to any load required.

The variable carbon resistance and shunt winding which are in parallel are both in series with a fixed resistance R, without which the regulation of the field current would be impossible.

The usual "cut-in" and "cut-out" switch is provided for connecting the dynamo to the battery, is shown at C, and operates a lever switch which closes contacts *a* and *b* and in the "off" position makes a contact *d*. An adjustable weight on the lever controls the voltage at which the dynamo "cuts-in."

A lamp resistance is also inserted in circuit when the dynamo supplies the lamps direct.

PINTSCH'S SYSTEM.

This system is supplied by the Pintsch Electric Manufacturing Co., of London, and is designed to supply constant voltage. The dynamo has inherent self-regulating properties, and does not require any auxiliary regulating apparatus. The following explanation will make plain the extremely simple principle upon which the voltage regulation is based. On referring to Fig. 11 C represents the commutator of the dynamo with its brushes A and B fixed in the neutral position, E represents the field winding, which is of a low resistance, requiring only ½ volt to cause a current of 4 amperes to flow, this current being sufficient to fully excite the machine at the lowest working speed. Assuming the dynamo is placed in parallel with, for instance, a 24 volt battery Z, the field winding being inserted in the connection V, there would obviously be no flow of current in E if the dynamo and battery voltages were both equal. Since there is no exciting current, the generator voltage would be at

zero, and a current would flow from the battery, but as the field winding only requires half a volt to become fully excited, the currents are once more equalized. It is evident therefore that the dynamo voltage can never fall more than half a volt below that of the battery, for if this could occur, the exciting current would be at once greatly increased with a corresponding rise in the generator voltage. For instance, suppose the generator is delivering current at a voltage of 23·5 volts, and the speed is doubled, the voltage will rise, but when it has increased by $\frac{1}{4}$ volt only (that is from 23·5 to 23·75 volts) the voltage across the field terminals will have fallen to $\frac{1}{4}$ volt. The exciting current has in consequence been reduced

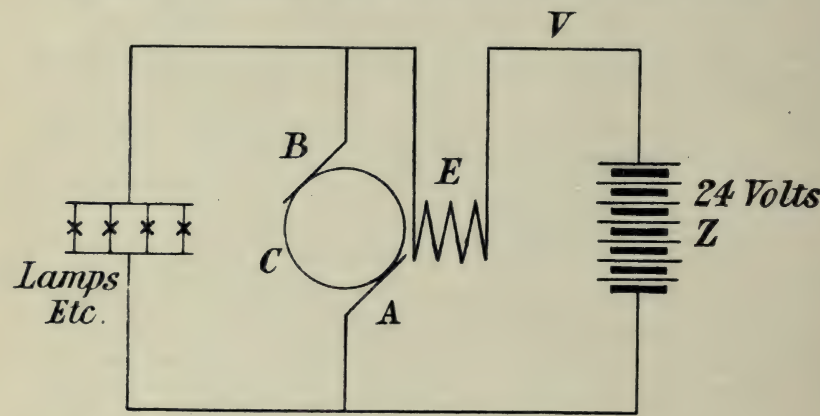


Fig. 11.

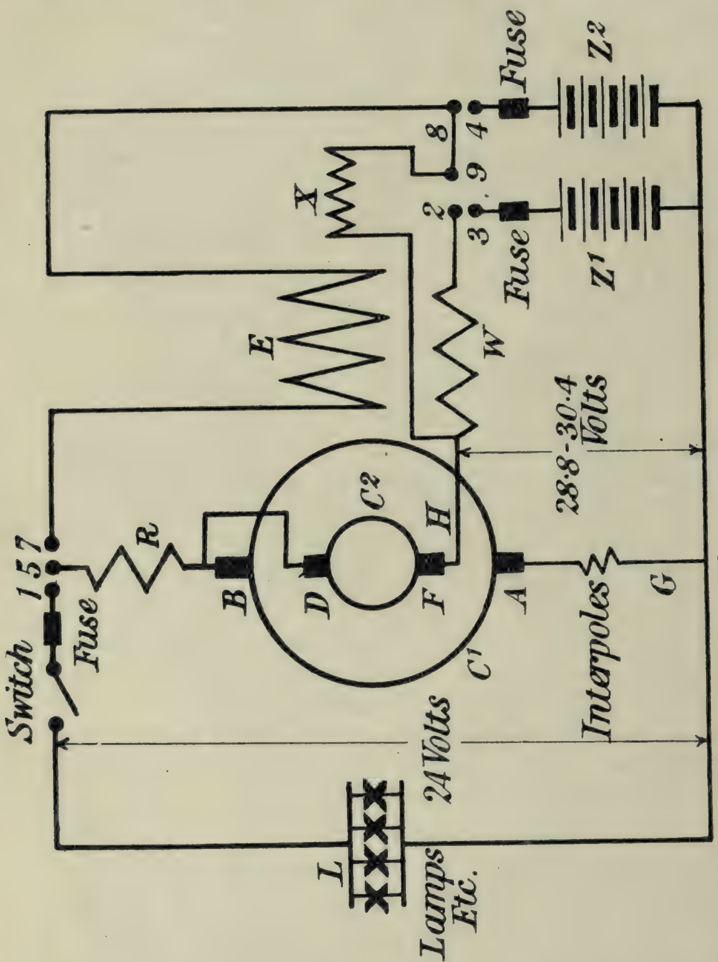
to half its value, and as the dynamo is now running at double the speed, the normal voltage of about 24 volts is again produced.

It is evident from the above that the regulation of the dynamo is practically infinite, and that at no increase of speed, can the voltage ever quite reach 24 volts, for if it were to do so, the exciting current would fall to zero, and the machine cease to generate any voltage (except that due to residual magnetism). For the same reason the voltage cannot drop, when the load on the dynamo is increased, for

immediately its voltage is lowered by an infinitely small amount, the extra excitation at once corrects the tendency. The regulation by these means is extremely close, in practice the dynamos run at speeds varying between 600 to 3,000 revolutions per minute, without causing a variation of voltage of more than about $\frac{1}{2}$ volt.

The necessary current is supplied during stoppages by means of the usual storage battery, which is divided into two halves, one half being used for exciting the generator, while the other is being recharged. The generator gives the voltage necessary for the lamps, say 24, but it must also be capable of generating a higher voltage in order to charge the half battery. For this purpose the armature is provided with two separate windings each connected to its own commutator, as shown diagrammatically in Fig. 12. One of the commutators C^1 with brushes A and B, gives a voltage of approximately that of the battery (say 24 volts) which is regulated in the manner described and shown in Fig. 11. The other commutator C^2 with the brushes D and F, is connected in series with the first, and adds to it a voltage of about 4·8 volts, giving between the brushes A and D an approximate voltage of $24+4{\cdot}8=28{\cdot}8$ volts, which is sufficient to cause a current to flow through one half of the battery. The lighting current then flows only through the 24 volt winding along the path B, 5, 1, L, 6 and A, the charging current on the other hand passes first through the 24 volt winding, and afterwards through the 4·8 volt winding along the path B, D, F, 2, 3, Z1, 6, G and A. As the additional armature winding runs in the same field as the main winding, it must also generate a constant voltage, and both windings together must produce the constant amount of 28·8 volts. During the time the lamps are burning, when there is a larger amount of current taken out of the battery, it is advisable to charge more strongly than during the day, and by inserting a resistance R between the generator and the point of connection of the exciting winding this purpose can be attained. Through this resistance the charging voltage is raised

automatically according to the number of lamps in circuit, so that a larger current consumption is compensated for by a correspondingly higher charging voltage. When the lamps are switched out the resistance becomes inoperative.



PINTSCH SYSTEM. Fig. 12.

The generator is made self exciting, so that in the event of the batteries becoming absolutely run down (through the carriage being put out of service or the lights left on for long

periods) they can become recharged when the carriage is again put into traffic. A small resistance X is connected permanently to the conductor H, while the other end 9 is automatically connected to that end of the field E, corresponding to the direction of rotation. 9 is connected with 8, so that on the dynamo revolving, current flows from brush D through B, 5, 7, 8, 9 and resistance X to brush F, thereby exciting the dynamo fields irrespective of the condition of the batteries. The current generated supplies battery Z1 and after the next stop battery Z2 (the batteries being automatically changed over) until normal conditions are restored.

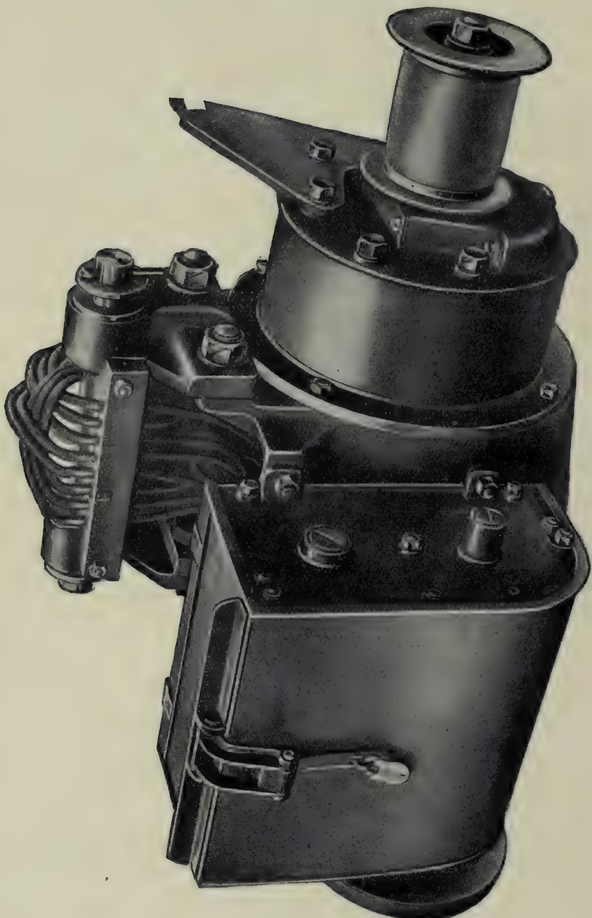
A voltage of 2·4 volts per cell, applied to a partially discharged battery, would pass too large a charging current, and to prevent this a limiting resistance W is inserted in the circuit as shown.

The "cut-in" switch for connecting the dynamo to the batteries is operated by a centrifugal governor, to which is also connected a reversing switch for changing over the batteries each time the dynamo cuts out.

The polarity of the current is rendered constant on changing the direction of rotation by reversing the direction of the exciting current through the fields.

The automatic switch contacts shown are inter-connected as follows:—Train standing—3 and 4 with 1, other connections open. Train travelling—Either 5 with 7 and with 1, 3 with 2 and 4 with 8, or, after the next stop, 5 with 7 and with 1, 3 with 8 and 4 with 2.

The dynamo Fig. 13 is of the usual train lighting type, easy of access, and of substantial construction. The pulley face is covered with a special composition to ensure a good grip on the belt and prevent slip. The switch gear is positively driven from the dynamo through gear, but only operates at cutting in or out, at other times running light upon ball bearings.



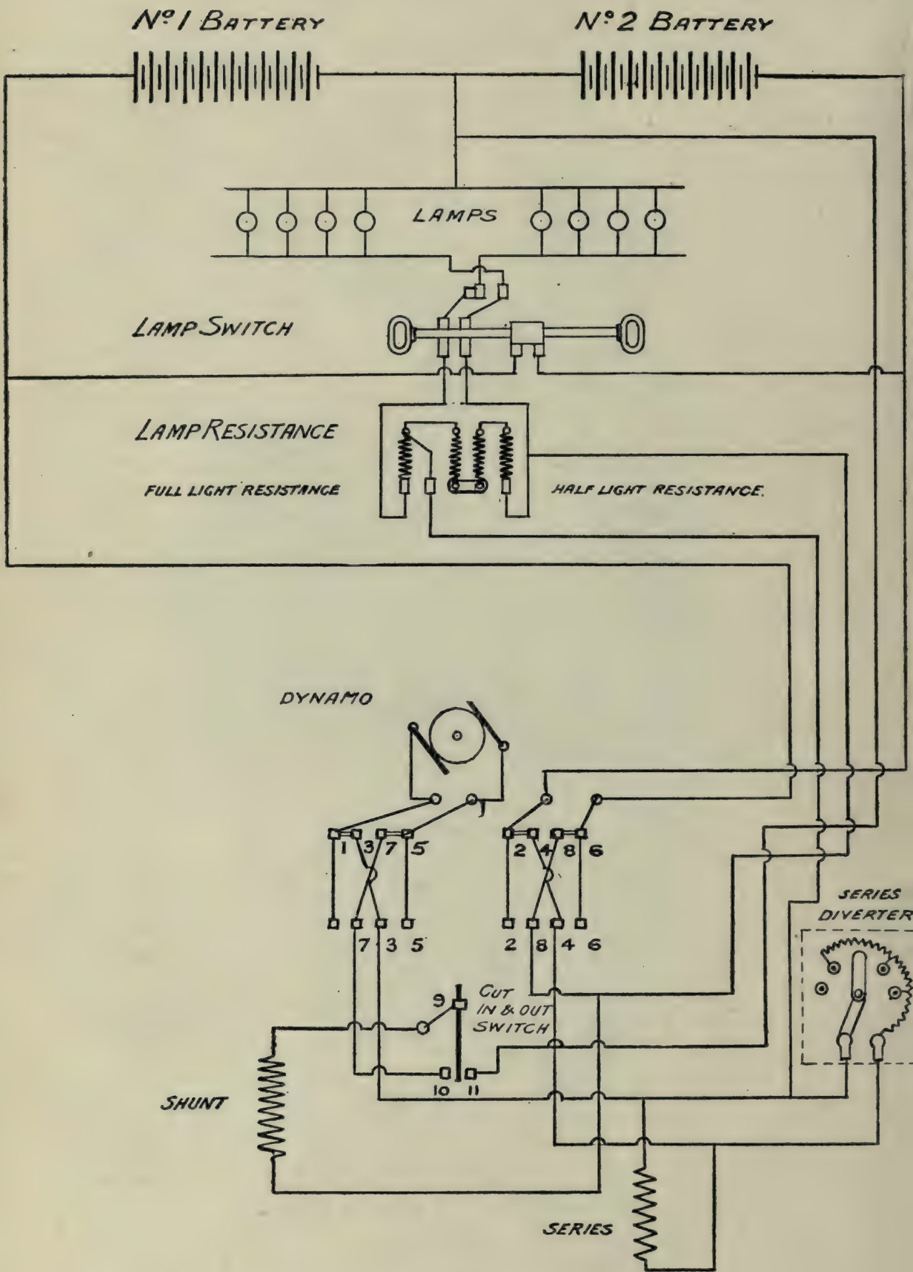
PINTSCH SYSTEM. Fig. 13.

SILVERTOWN SYSTEM.

The equipment consists of a dynamo driven from the carriage axle, and carrying on its shaft a governor which is used to operate the switch gear; also a double battery of accumulators, one of which is normally connected to the terminals of the lamp circuit, whilst the other is connected to the dynamo terminals so that it may receive a charge.

The dynamo is of ordinary construction and design except that the field magnets are differentially wound, one winding being a shunt winding connected by the switch gear to the terminals of the battery which at any given time is connected to the lamps (hereafter called the discharge battery), whilst the other is a series winding, through which is passed the whole or a part of the current supplied by the dynamo to the second battery, called the charge battery. This winding is connected up by the switch gear so that it opposes the shunt winding, and tends to demagnetise the magnets and weaken the field in which the armature is rotating.

Connected as a shunt across the series winding is a resistance or diverter, which can be adjusted by hand to regulate the proportion of the charging current passing through the series winding; so that if the conditions of working are such that there is an increase in the ampere hours of discharge from the batteries, the rate of charge of the charge battery can be increased, or if there is a decrease, the rate of charge can be decreased. By so adjusting the diverter resistance that, with any predetermined value of the charging current, the proportion of this current passing through the series coils gives a demagnetising effect equal to the magnetising effect of the shunt coils, the charging current can be limited to something less than this predetermined value, as if the charging current could reach this value, there would be no magnetising force and the dynamo could not generate and consequently could not supply any current to the battery. At the same time, as none of the current passing to the lamp circuit passes through the series coils, their demagnetising



SILVERTOWN SYSTEM. Fig. 14.

effect is not dependent on the number of lamps in circuit, and whether full, half, or no lights are on, it will still be impossible for the charging current to reach the predetermined value. The armature shaft of the dynamo carries a centrifugal governor, so arranged that it operates a "cut-in" switch when the speed of the armature is such that the dynamo, excited by the shunt coils only, gives a voltage equal to the normal lamp voltage. This "cut-in" switch first connects the shunt circuit to the discharge battery so as to excite the dynamo, and then connects the armature of the dynamo to the charge battery through the demagnetising series coils and its diverter, and to the discharge battery and lamp circuit through the lamp resistances.

The governor also carries on its collar a projection, which as soon as the armature begins to rotate, engages with a rocking lever operating a reversing switch (provided there has been a change in the direction of the rotation of the armature). This collar works against a light spring for the first half inch of its movement, so that when making only a few revolutions per minute it is quickly drawn away by the governor, sufficient for the projection to be clear of the rocking lever, and thus prevent the repeated striking of the former against the latter. This reversing switch not only changes the connections between the armature and the batteries so that the dynamo gives current in the proper direction, but also changes the batteries over so that the one formerly the discharge battery becomes the charge battery and *vice versa*. In addition to the above apparatus, a lamp switch is provided, so that all the lights, or half lights can be switched on, and this also couples the two batteries in parallel for charging when all lights are switched off.

Referring to Fig. 14 which is a diagram of the wiring, if we assume the train is just starting and all the lamps are switched on, the direction being such that the reversing switch is in position shown by the full lines (upper contacts), the current will flow through the various circuits in the following manner:—From No. 1 Battery and upper contacts

6 and 8, to lamp switch and lamps, back to No. 1 Battery. A part of the current will be supplied by No. 2 Battery through contacts 2 and 4 through the series winding and its diverter, then through the lamp resistances to the lamps and back to No. 2 Battery.

When the speed has been increased sufficiently, the shunt winding will be connected to No. 1 Battery to excite the shunt through contacts 6 and 8 to shunt coils, and contacts 9 and 11 back to No. 1 Battery, thus ensuring the voltage being built up before the armature is connected with the batteries and lamps.

An increased speed will now connect 9 and 11 to 10, and the armature will supply current to the load in the following manner :—The current passes from the armature to contacts 1 and 3, after which it divides, part going through the lamp resistances to the lamps and part through the series winding and its diverter and contacts 4 and 2 to No. 2 Battery (which is the charge battery when running in this direction). The current from No. 2 Battery will now join that from the lamps and pass through contacts 11, 10, 7 and 5 back to the armature.

If only half lamps are required, the current will flow as before except that there will be no circuit through one group of lamps, nor through one of the lamp resistances which were in parallel for full lights. In the event of no lights being used, the two batteries are placed in parallel by the act of switching the lights off. In this case, the current will flow in the following manner :—From the armature to contacts 1 and 3 after which it divides, part going to the series winding and its diverter and part to the half-light lamp resistance.

The current after passing through the series winding diverter and lamp resistance in parallel, again divides, passing through both batteries and the shunt winding in parallel, and through contacts 11, 9 and 10, to 7, 5 and the armature.

This system is manufactured by the Indiarubber, Gutta Percha and Telegraph Co., of Silvertown, London, E.

STONE'S SYSTEM.

This lighting system. the property of Messrs. J. Stone & Co., of Deptford, London, was the earliest in the field of self-contained carriage lighting systems, and is still in extensive use.

The voltage regulation is effected by purely mechanical means and is fairly free from complication.

The dynamo is an ordinary shunt wound machine of simple type, and those of recent date are fitted with ball bearings. Upon the method of suspending it from the underframe, however, its feature of self regulation depends.

In dynamos, depending for their control upon electrical means, the centre of gravity of the machine as a rule lies below its point of suspension, but in the Stone system the dynamo is hung so that its weight puts the necessary driving tension on the belt.

This is effected as shown in Fig. 15. The dynamo is attached by a loose hinge to an adjustable link, held in position by a tension screw.

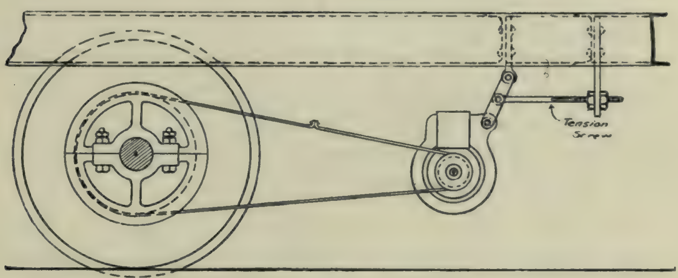


Fig. 15.

The point of suspension of the dynamo is at one corner, so that if free to move it would swing away from the axle driving pulley. The tension screw and belt are, however, adjusted so that the dynamo is held by the belt, out of the position in which it would naturally hang, and a certain

tension is thus put upon the belt. This tension can be regulated by screwing or unscrewing the tension screw, so that more or less of the weight of the dynamo is made effective.

When an increase in the speed of the carriage takes place the dynamo endeavours to generate a greater output, and consequently requires more power to drive it. The power put into the dynamo, however, depends upon the belt tension, and consequently when (due to the increase in speed) the tension on the belt exceeds that due to the one-sided suspension of the dynamo, the belt will slip, and no matter at what speed the axle pulley may be revolving the speed of the dynamo pulley will remain practically constant. The armature cannot, therefore, be revolved faster than a definite speed, depending upon the tension put upon the belt, and the voltage is thus maintained approximately constant.

The dynamo, which is of simple and robust construction, carries a small switchboard at its commutator end, upon which is mounted a " cut-in " and " cut-out " switch. A centrifugal governor with adjustable weights is fixed to the end of the armature spindle, and to the movable sleeve of this is secured a " rocking " or partially rotatable arm to which is attached the main movable contacts.

On the rotation of the armature, the " rocking arm " is first carried round by means of a friction device to certain limiting stops, and as the speed increases the governor weights fly out, moving the sleeve with the " rocking arm " along the shaft, closing certain knife contacts which connect up the dynamo, battery, etc., in the correct order.

The " rocking arm " in its travel also operates a reversing switch, which determines the direction in which current shall flow in the circuit.

To prevent the arc which is formed when the dynamo switch is opened, from burning the contacts, a carbon " break " is arranged to be brought into operation by the movement of the " rocking arm," and the arc is broken at the small carbon contacts.

The friction device for partially rotating the " rocking arm " consists of two rotating spring plungers carrying hardwood blocks, which are pressed on a channelled ring forming part of the " rocking arm," and consequently carrying it round until it meets the stops. To prevent the excessive friction and wear which would be caused if the device were always in operation, the plungers fly out by centrifugal force as the speed increases, and consequently press no longer on the " rocking arm " ring.

The simple diagram in Fig. 16 illustrates the principle of the system.

Two batteries are employed and are so arranged that while one receives a small charge the other regulates the voltage to the lamps. On reversal of the direction of motion, the battery connections are automatically reversed by the reversing switch, and the battery last charged becomes the regulating battery, while the other one receives the charge.

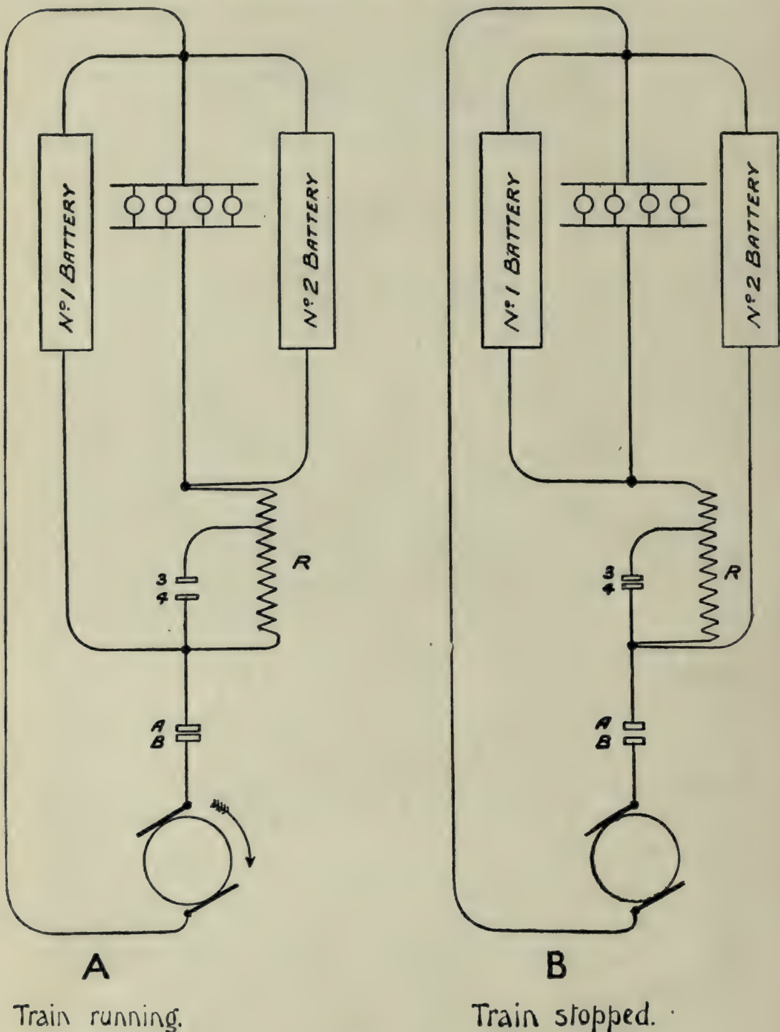
Since the dynamo must generate a higher voltage than the lamps require to properly charge the batteries, a resistance is placed in circuit to prevent the lamps from being over-run. In Fig. 16, diagram A, showing dynamo running, contacts A and B are closed and 3 and 4 open. Current then flows direct through No. 1 battery, and resistance to the lamps, No. 2 battery being directly connected to the lamps.

When the train stops (Fig. 16, diagram B), contacts A and B are opened and 3 and 4 closed, No. 1 battery now supplying part of the current required, through 3 and 4 and portion of the resistance; and No. 2 battery supplying direct to the lamps.

These operations are reversed when the carriage reverses its direction of motion. Fig. 17 shows the connections in fuller detail, D representing the actual switchboard of the dynamo.

If the dynamo is running in the direction indicated by the arrow the " rocking arm " will be moved round until its contacts are over C, A, B, 2 and 1. As the speed increases

the contacts first join A and B, thus exciting the dynamo field from No. 1 battery. On attaining the speed at which the governor is set to operate the "rocking arm" contacts are



STONE'S SYSTEM.

Fig. 16.

pushed home, joining C to A and B and No. 2 to No. 1, at the same time opening contacts 3 and 4 and connecting the reversing switch to D.

Current now passes from the bottom brush through C to A and B, and thence round the field magnet circuit. From A it passes to D and then to terminal $+^1$ on resistance terminal board, thence to the positive pole of No. 1 battery (part going through the resistance to No. 2 battery if the lamps are off), returning through the common negative to the — terminal on the resistance board and back to contacts 2, 1 and top brush.

When the direction of the dynamo's rotation is reversed the "rocking arm" is carried partly round until its contacts are over C^1, A^1, B^1, 2^1, 1^1.

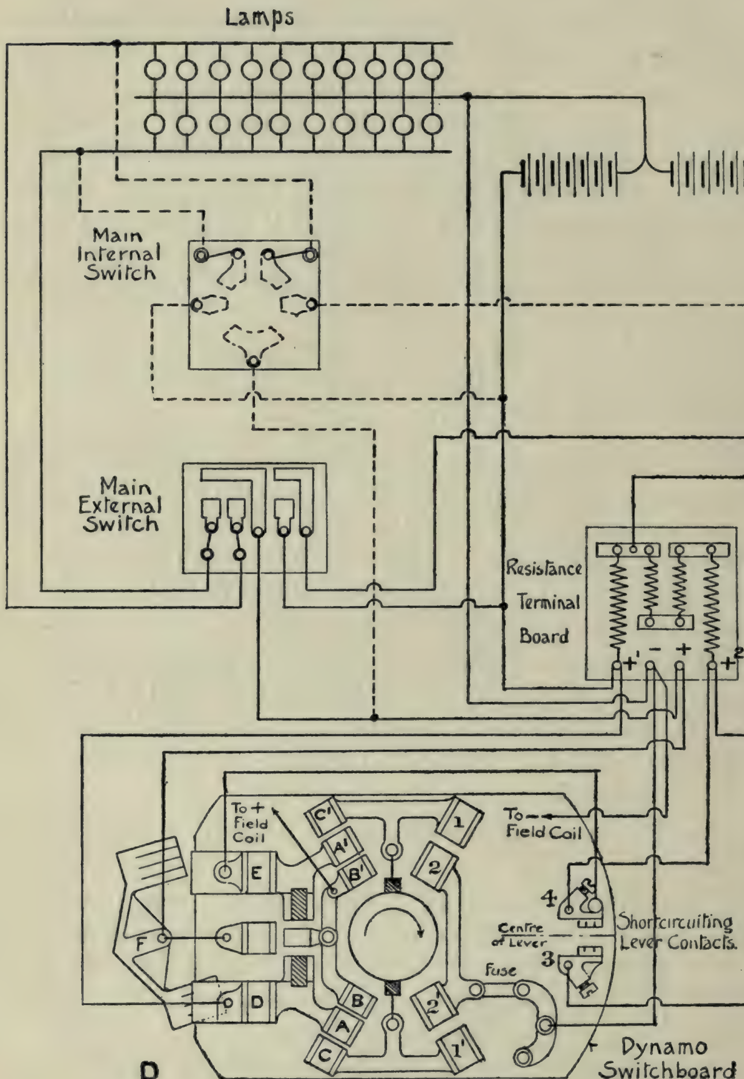
A^1, B^1 are first joined to excite the dynamo, and afterwards the others, while the reversing switch is joined to E. Current then flows from A^1 to E, E to 4, and 4 to $+^2$ on terminal board, from this to + of No. 2 battery (and through resistance to No. 1 battery if the lamps are off) returning through negative main to 2^1, 1^1 and bottom brush.

If the lamps are now brought into use current will flow from the dynamo through the resistance to terminal $+^1$, from $+^1$ to D, D to F and + on the terminal board, from this terminal to the lamp switch and through the lamps back to the — terminal.

No. 2 battery thus receives a charge while No. 1 serves the lamps.

If the train stops and lights are in use, contacts 3 and 4 are closed as the others open, and current passes from No. 1 battery through $+^1$ to D, F and + to lamps. No. 2 battery also discharging through 3 and 4 and part of the resistance to $+^1$ and thence to the lamps.

The differences in voltages between the two batteries is compensated for by the resistance.



STONE'S SYSTEM.

Fig. 17.

T. A. C. SYSTEM.

In this system, which is supplied by the Tudor Accumulator Co., of London, the object has been to avoid moving regulating apparatus.

The dynamo is a differentially wound machine with both shunt and series windings, the series winding giving the necessary demagnetisation at high speeds. The polarity of the current is maintained in one direction by means of a rotating brush rocker, mounted on ball bearings.

A large portion of the series winding passes through diverters, in order to give flexibility of operation, as should a reduced output be desired the diverters have merely to be altered.

The output of the dynamo can, of course, also be altered by varying the shunt field current, and this is the method of regulation.

The dynamo runs on ball bearings and has modern improvements, while the commutation is good even at very high speeds.

The essential "cut-in" and "cut-out" dynamo switch is provided with a shunt coil connected across the dynamo brushes, and a series coil in the main dynamo circuit.

When the dynamo generates the necessary voltage, the shunt coil closes the switch and connects the dynamo to the battery, the series coil assisting to keep the switch contacts securely closed. When the dynamo slows up, the voltage across the brushes falls until slightly below that of the battery, a reverse current then flows through the series coil, which opens the switch and disconnects the dynamo from the battery.

To prevent overcharging of the battery, an overcharge switch is employed, which has an actuating coil connected across the dynamo terminals, and therefore across the battery when the main switch is closed. The overcharge

switch is set to open when the battery becomes fully charged and does not close again until the dynamo comes nearly to rest. The closing of the switch reduces the resistance in series with the field circuit, while its opening increases it (according to the load in circuit) and thus cuts down the output.

Only one battery is used and this is permanently connected to the lamps as long as they are alight. In order to counteract the voltage fluctuations due to the battery being either on charge or discharge, each lamp has, inserted in series with it, a special iron wire resistance which absorbs the fluctuations and keep the voltage constant within close limits.

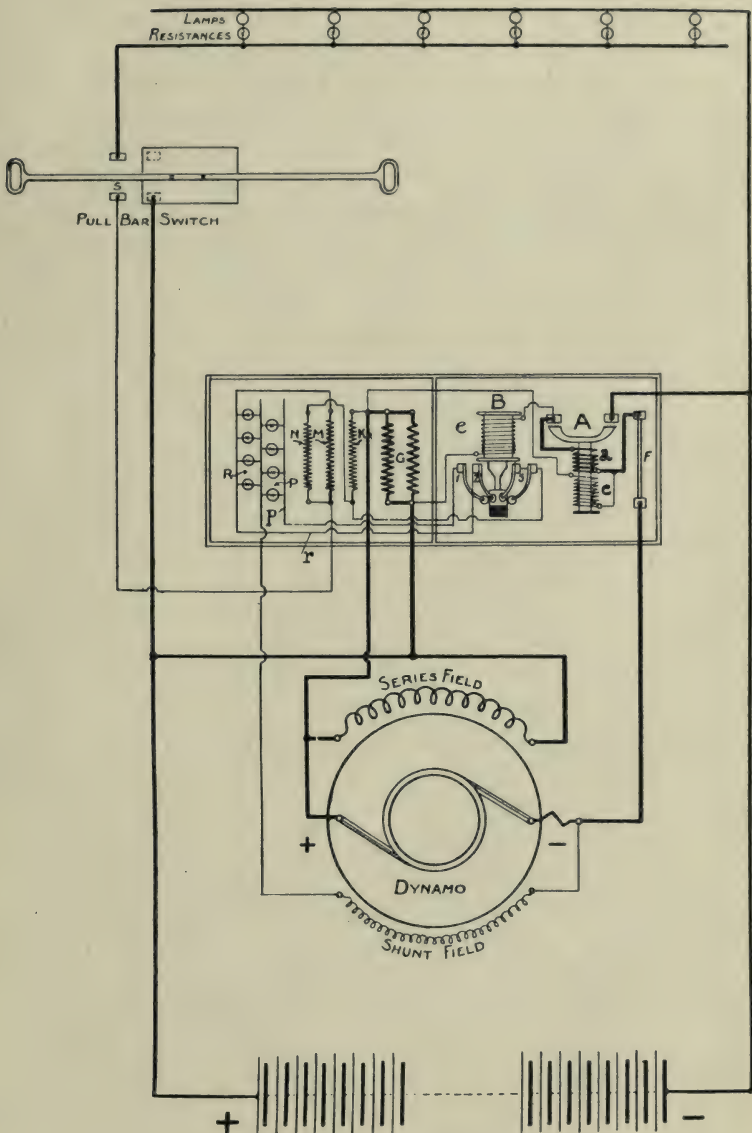
As these resistances naturally cause a loss of voltage, 15 cells are employed in a 24 volt system instead of the usual twelve.

Fig. 18 illustrates the wiring of the system and its operation is as follows.

Supposing the carriage to be at rest and the lamps switched on, they will be supplied by the battery. There will be no voltage across coil *c* of the main automatic switch A or coil *e* of the overcharge switch B since these are both connected with the dynamo, the two switches will therefore be in the open and closed positions respectively.

When the carriage starts and the dynamo commences to rotate, the brush rocker will first move (due to the friction of the brushes on the commutator) into the position to give the correct polarity to the current in the external circuit, the dynamo will excite and the current pass from the negative brush through the shunt field winding to the two groups of resistances R and P which are of the iron wire type, and allow a definite current to pass through them independent of a large fluctuation in voltage.

The current divides and a definite portion passes to the terminals 1 and 2 of the overcharge switch; through its armature, and thence through resistance K to the positive brush.



T. A. C. SYSTEM.

Fig. 18.

As soon as the dynamo attains a speed of 300 revolutions per minute it generates the necessary voltage and the main switch closes, connecting it to the battery and lights; as the speed further increases the output rises, and when the current exceeds the lamp load the excess goes to charge the battery.

After a certain time the battery becomes fully charged, and its voltage rises until it reaches the point at which the overcharge switch is set to rise; in rising it disconnects terminals 1, 2 and 3, so that the field current cannot pass to the group of resistances P, and these are therefore cut out of circuit. This has the effect of reducing the field current by the amount which previously passed through it, and of thus reducing the dynamo output to the lamp load; which the field current still flowing through the group of resistances R and M is just sufficient to maintain.

If now the lamp switch is opened the field current is reduced to a very small value as it can only pass to the positive brush through the resistances RM, high resistance N, and resistance K. This small field current is just sufficient to make the dynamo generate 2 or 3 amperes, and serves to "top up" the battery and keep the main and overcharge switches from "hunting."

As the dynamo slows up the output falls gradually and the main switch opens, while when it comes nearly to rest the overcharge switch closes.

It will be seen therefore that provision is made for the dynamo after every stop to give the full output on starting again until the overcharge switch comes into action, the output being then regulated to suit the load in circuit.

The special resistances consist of iron wire in an atmosphere of hydrogen and are made and inserted in circuit in a similar way to incandescent lamps, which they in some measure resemble.

VICARINO SYSTEM.

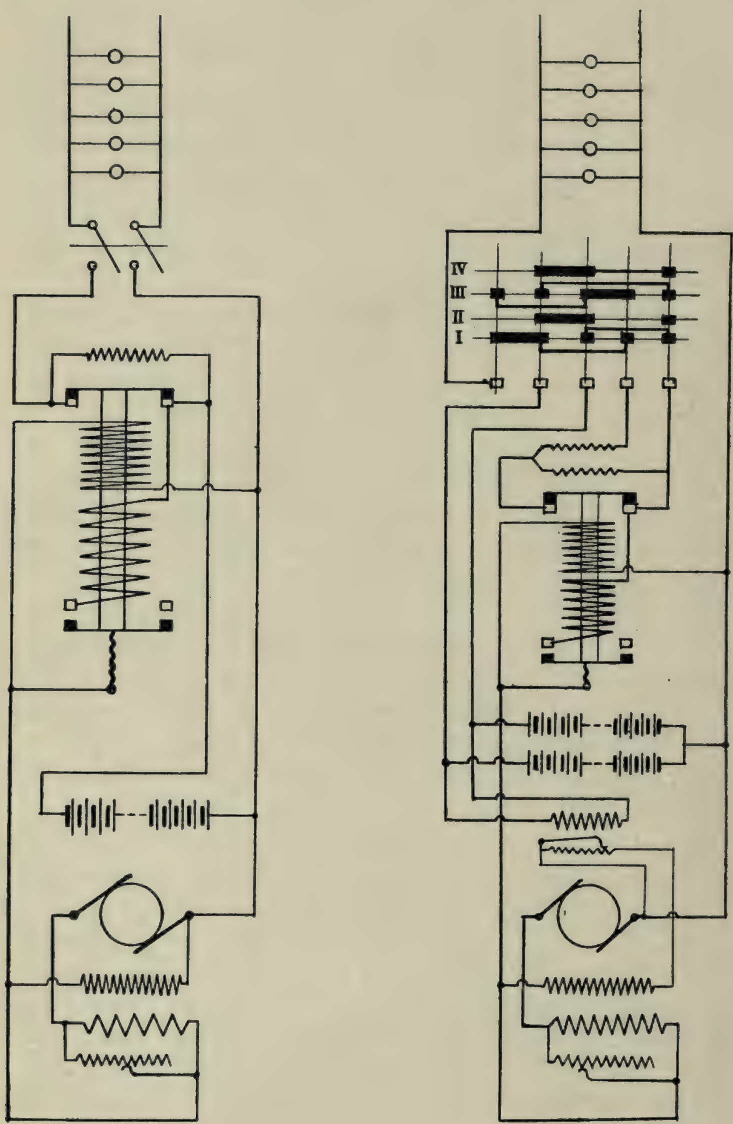
This system, which is the property of the General Electric Co. of France, is in extensive use on the Continent, being of very simple design and without supplementary apparatus. It consists of a dynamo, battery, and "automat" or magnetic "cut-in" switch, which also exercises the function of controlling the battery output.

Three modifications of the system are in use—one operating with a single battery, another with a double battery (32 volts), while a third uses a double battery which is charged in series at 32 volts, and discharged in parallel (16 volts).

Single Battery.—The dynamo is of the usual train lighting type, and is provided with shunt and series windings in opposition, as shown in A Fig. 19. The automat connects the dynamo and battery, when the voltage of the former reaches that of the latter, and at the same time inserts a resistance in the lamp circuit. The dynamo current is therefore distributed in two parallel circuits, one, of high resistance, to the lamps, and the other, of low resistance, to the battery. The differential windings of the dynamo are so proportioned that if the output exceeds that required by the lamps, the excess supplies the battery, the lamp voltage being kept approximately constant.

Double Battery.—On the operation of the automat the dynamo charges one of the batteries direct, the other discharging to the lamps through a resistance and maintaining a constant voltage. When the train stops the two batteries supply the lamps in parallel, but the operation of the automat interposes between the battery being charged and that discharging, a portion of the regulating resistance, in order to equilibrate the voltage of the two batteries so as not to overrun the lamps.

The lamp switch is of the commutator type, and is arranged to change over the batteries each time it is operated, so that the charged battery becomes the discharging one and *vice*



A **B**

VICARINO SYSTEM.

Fig. 19.

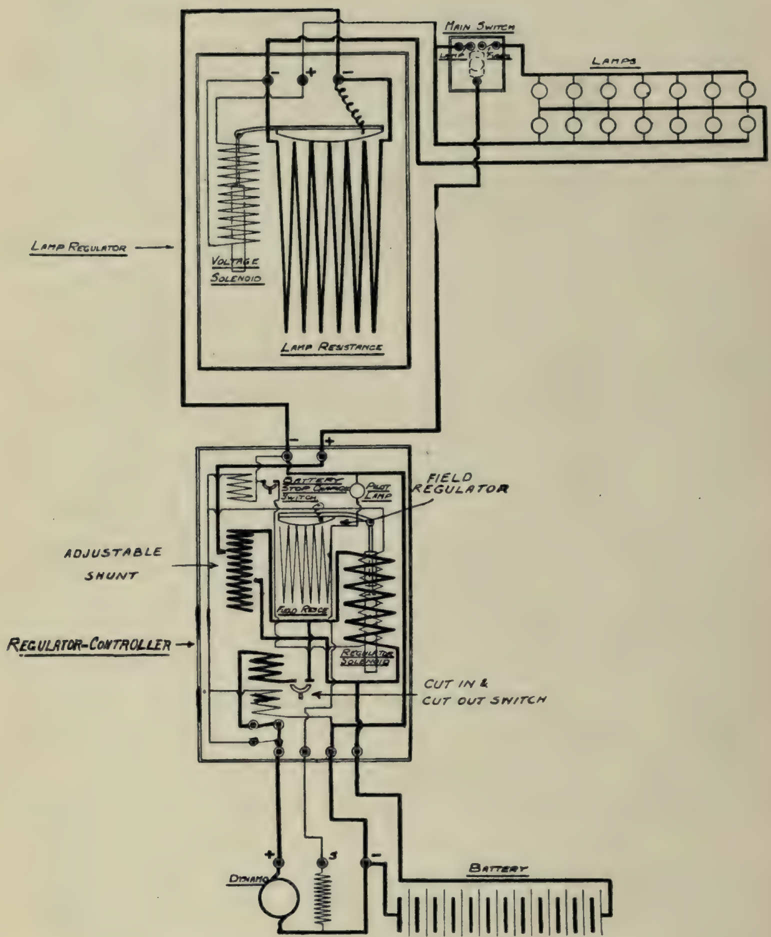
versa. The diagrams of connections in B Fig. 19 will explain this, the contacts of the commutator switch being shown in plan. Flexible metal brushes collect the current and distribute it to the various circuits. The switch positions are shown at I., II., III. and IV., a quarter of a turn sufficing to make the connection. In position I. the lamps are supplied by No. 1 Battery, in position II. they are extinguished, and the batteries placed in parallel, at III. the lamps are supplied by No. 2 Battery, and at IV. they are extinguished, and so on. The switch is arranged so that it cannot be turned backward, but must always be operated in a forward direction.

VICKERS SINGLE BATTERY SYSTEM.

This system is supplied by Messrs. Vickers, Ld., Westminster, London, and consists of a dynamo, regulator controller, lamp regulator and single battery. The dynamo is a shunt wound machine of normal construction, either ring-oiled or with ball bearings, and the direction of polarity of the current is kept constant by the usual device of a rotating brush rocker, which, however, by turning rather more than a quarter of a revolution with the armature (against adjustable stops) permits of suitable "lead" being given to the brushes, of which four are provided to equalise turning strains.

The regulator controller, see Fig. 20, which is enclosed in a dust proof and waterproof box, is a combination device comprising—*a*, field regulator; *b*, dynamo "cut-in" and "cut-out" switch; *c*, adjustable shunt for varying output or lamp load; *d*, battery stop charge switch.

The field regulator consists of a high resistance, composed of metallic grids connected with a number of contacts, built up with insulating sections so as to form a continuous curved path. Over this a curved "contactor" rolls in such a way that when tilted to the full extent one way the whole of the



VICKERS SINGLE BATTERY SYSTEM.

Fig. 20.

resistance is short circuited, while when tilted the other way the whole of the resistance is thrown into the dynamo field circuit. The contactor has a spreading effect, which ensures good contact in all positions. The contactor is operated by a compound wound solenoid, the plunger of which is governed by a special air dash pot to ensure evenness of movement.

The main winding of the solenoid is connected in series with the dynamo. In this manner any rise of output above the normal tilts the contactor so as to put more resistance in the dynamo shunt, while, conversely, any fall of output tilts it so as to reduce the shunt resistance

The other winding is of fine wire and comes into operation when the battery has become fully charged and its voltage correspondingly risen. It is then thrown into action by the battery stop charge switch, and assists the series winding so as to still further reduce the output.

The dynamo "cut-in" and "cut-out" switch consists of two fixed laminated contacts and a movable bridgepiece, connected with the armature of the operating electro magnet, so that the switch closes when the armature is attracted and opens when it falls away again. It is operated by a compound wound magnet, the shunt coils of which are connected across the main dynamo terminals, and these are in turn reinforced by the series coils which carry the main dynamo current.

The adjustable shunt or diverter consists of a low resistance, so arranged that by means of flexible leads any desired amount of resistance can be connected in parallel with the main coil of the regulator, and consequently the dynamo output can be varied as desired.

The lamp current is also taken from this resistance by a flexible lead, and any desired proportion can be passed through the regulator shunt.

By these means regulation can be effected on the total dynamo output, or battery charging current, or a combination of the two.

The battery stop charge switch is similar to the dynamo switch, but smaller. When closed it throws the shunt coil of the regulator solenoid into action. The operating magnet is shunt wound and is connected across the dynamo mains.

By means of a graduated cam, which varies the air gap between the armature and its magnet, it can be adjusted so as to close when the battery has become fully charged.

The lamp voltage regulator consists of a similar solenoid operated switch and resistance, to that employed for the dynamo field regulation, but its resistance elements are larger as it has to deal with heavier currents. The solenoid is connected in shunt directly across the lamp circuit, and compensates for any rise or fall in voltage by automatically varying the resistance in circuit.

The main and shunt circuits are protected by fuses, and a pilot lamp is also fitted, which gives a visual indication that the dynamo is generating.

Fig. 20 shews the wiring diagram complete with internal circuits of the regulators.

BATTERIES.

CHLORIDE "LUX" ACCUMULATOR.

This accumulator is manufactured by the Chloride Electric Storage Co., Ld., of Manchester, who have devoted their attention to improvements in detail with the object of increasing the strength and consequently the life of the cell.

In the "Lux" accumulator the positive place consists of a hard lead alloy grid or framework cast under pressure, into holes in which the active material in the form of rosettes of pure lead tape is placed. The grid possesses great mechanical strength and is not acted upon by the electrolyte; it therefore retains its shape and dimensions and is not likely to buckle. The rosettes permit of the free access of the electrolyte through the plate to ensure uniform working conditions over the whole of the active surface.

The separator consists of a continuous diaphragm of wood which entirely covers the surface of the plates, and thus prevents internal short circuiting; it also has the effect of maintaining the capacity of the cell by keeping a reserve of electrolyte, when in ordinary circumstances it would decrease. The wood is specially treated under patents owned by the Chloride Co. in order to remove constituents in the wood which would injure the plates.

The negative plate is of the box or cage type and consists of two halves which are riveted together after the paste has been inserted. Each half is formed of a latticed frame cast on a sheet of perforated lead, the paste is therefore held in a series of pockets so that it is impossible for it to fall away.

A view of the complete element is shown in Fig. 21, the groups being drawn apart in order to show the positive group.

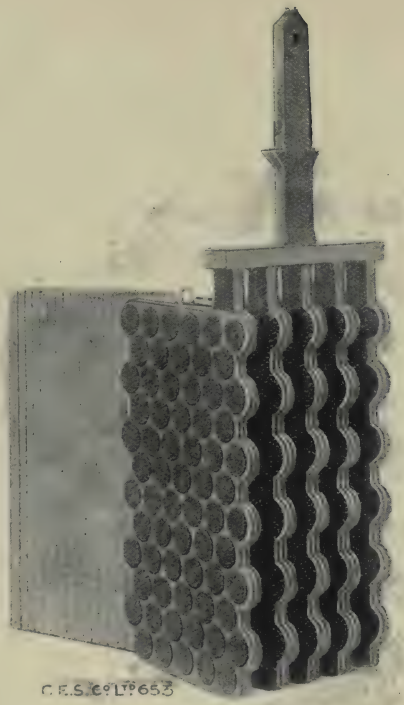
The box is made of teak, lined with hard lead alloy sheet, the idea being that it is not only mechanically stronger, but better able than pure lead to withstand the corrosive action of the electrolyte.

Ample space is allowed above the plates for acid, and below them for accumulation of sediment, in order that the cells may run for long periods without washing out.

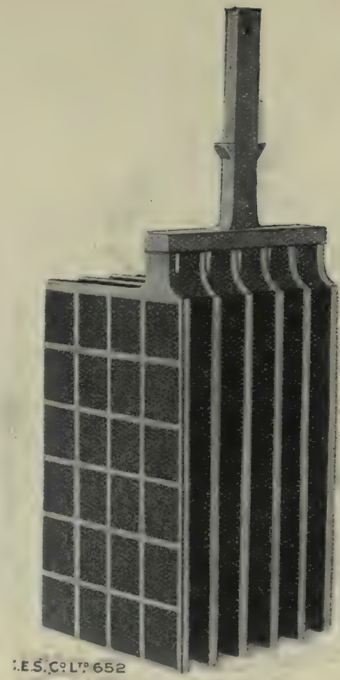
The lid is made extra deep with anti-splash grooves, and is fitted with rubber gaskets through which the lugs or connectors pass. The holding down bolts are of T shape, and can be easily renewed without damaging the box. They are spaced in such a manner that the lid can only be put on in one way, and thus confusion in coupling up is avoided, since the positive and negative lugs can only be put through their respective gaskets.

The bottom blocks are made of teak and are of very simple construction.

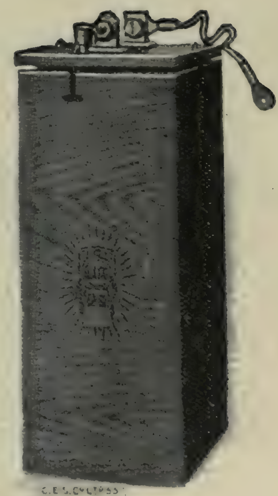
The "Lux" accumulator is now supplied in glass boxes, with glass lids, inspection being thereby rendered very easy, while the ebonite sheets, lead lining, etc., can be dispensed with.



Positive Group.



Negative Group.



Complete Cell.

"LUX" ACCUMULATOR. Fig. 21.

PRITCHETT ACCUMULATOR.

This accumulator, manufactured by Messrs. Pritchetts and Gold, Ltd., London, is representative of the modern type of Train-lighting Cell with Planté positive plates, but has special features to commend it.

The positive plates are of Planté formation, and are very strong and durable, while owing to the special design of the plate an exceedingly large surface is exposed to the electrolyte and consequently a large reserve of lead obtained for future oxidisation. The negative plates are of the box grid type, the grid being designed with strengthening bars to give it the maximum strength, while the paste has the special feature of retaining its porosity and its capacity for many years longer than is the case with the ordinary paste used in the old type open-grid negative plates.

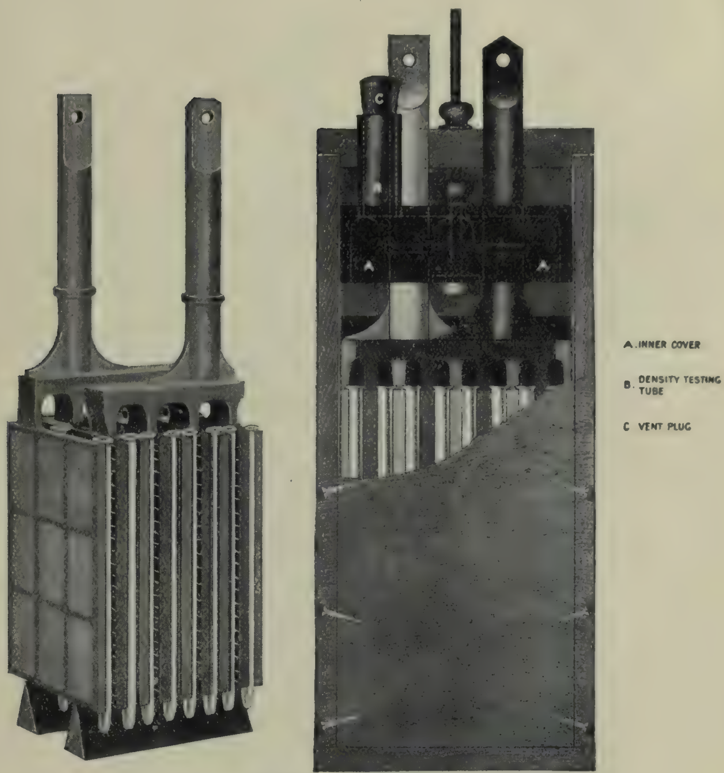
Fig. 21 shows the positive and negative sections with their strong and heavy bus-bars and vertical lugs. The bus-bars are burnt on to the plates by hand in preference to casting them, to ensure a perfect metallic joint.

The plates are separated a distance of $\frac{5}{16}$in. by specially strong glass tubes, which are kept in place by grooves in the plates. Wood or ebonite separators can, however, be fitted in place of glass tubes if preferred.

The containing boxes are of teak, screwed together and lined with stout sheet lead after both box and lining have been treated with a special acid-resisting compound made by Messrs. Pritchetts & Gold, Ltd.

To prevent splashing and leakage and consequent loss of electrolyte, a patent double lid is fitted as shown in Fig. 22.

The inner cover which is made of "Dagenite" a hard acid-proof composition, rests on shoulders on the vertical lugs, and owing to its internal shape quite prevents any splashing. To keep out dust, sand, etc., an ordinary lid is also fitted but is not fixed in any way, it having been found



PRITCHETT ACCUMULATOR.

Fig. 22.

that the anti-splashing qualities of the inner cover render this unnecessary. It is claimed that a great saving of time is effected when dismantling cells owing to the use of these double lids and the topping up with water is rendered much less frequent.

E.P.S. ACCUMULATOR.

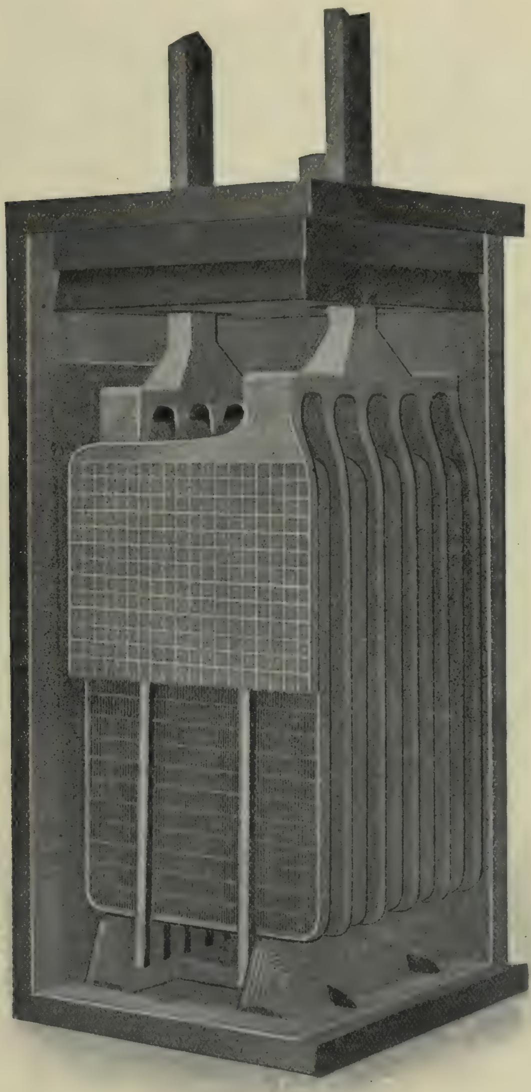
Although the above accumulators, which are manufactured by the Electrical Power Storage Co., Ltd., of London, have many features in common with others illustrated; mention must be made of them, as they may be said to be the pioneer cell for train lighting, several railways adopting them 25 years ago for " Brake Van " systems.

At that time pasted plates were fitted, the positive plates being composed of a central diaphragm with ribs of triangular cross section, the negatives being of the lattice type, with vertical and horizontal ribs forming cages for the reception of the paste.

A " Planté " type of plate is now made, however, cells of this type giving 12½ per cent. greater output than those of similar dimensions of the pasted type, which are, however, still preferred by some.

The usual practice for train lighting cells is followed, lead lined teak boxes containing the plates, which are separated by grooved wood separators, Fig. 23 showing the complete cell.

Other large and up-to-date makers of train-lighting accumulators are The "D.P." Battery Co., The Hart Accumulator Co., and The Tudor Accumulator Co., whose accumulators, although varying slightly in design, construction and special features from those already mentioned, are not so different as to necessitate special description.

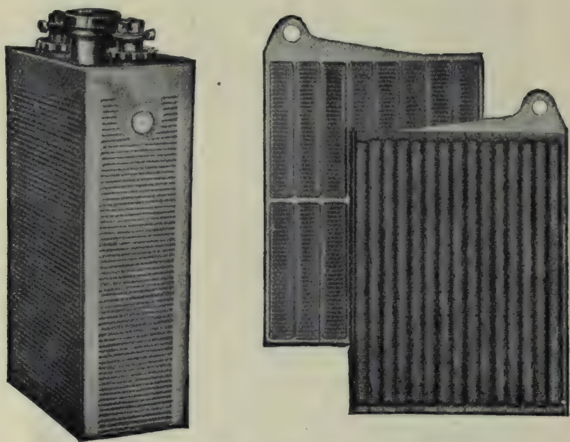


E.P.S. ACCUMULATOR
Fig. 23.

EDISON ACCUMULATOR.

In this accumulator quite a novel construction is employed in place of the lead and sulphuric acid elements common to other secondary cells.

The so-called positive or depolarising plate is a structure built up of two rows of spirally wound perforated steel tubes, the seams of which are double lapped. Each tube is filled with several hundred tightly packed alternate thin layers of nickel hydrate and flake nickel forming a solid column of conducting material.



EDISON ACCUMULATOR.
Fig. 24.

The negative plate is also of nickel steel, it holds a peculiar oxide of iron in thin perforated lozenge shaped steel pockets, each pocket independently mounted in a punched steel frame.

A complete cell consists of a series of positive and negative plates mounted in a light steel container, the terminals projecting through stuffing glands in the welded-in cover thereof. Adjacent plates are insulated by means of hard rubber frames and strips, sufficiently tight to prevent movement.

The cover is fitted with a filler cap for adding distilled water, the cap incorporating a gravity gas valve to permit the escape of gas during electrolytic action.

The electrolyte is a special solution consisting principally of potassium hydrate, and actually preserves steel.

Several practical advantages are claimed for the Edison method of construction, chief of which are perfect freedom from such defects as are analagous to plate buckling, growing, shedding of active material, excessive loss of charge, and deterioration on open circuit.

The accumulator is also unharmed by very high rate charging, or even by discharging at rates up to the short circuiting rate, it may also be subjected to severe and prolonged vibration without serious harm ensuing.

The voltage of the Edison cell is only 1·2 volts.

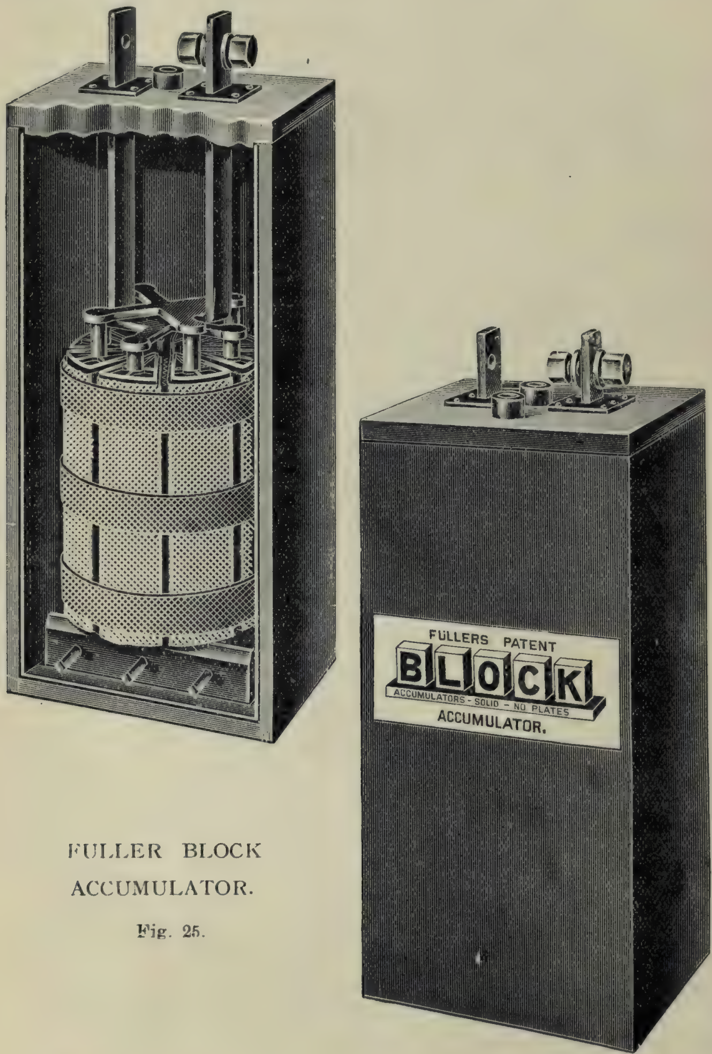
FULLER BLOCK ACCUMULATOR.

This cell, which is manufactured by the Fuller Accumulator Company, Ltd., Bow, London, is a departure from the usual type of plate cell, the elements being constructed of triangular blocks. It is claimed that great mechanical strength is thereby provided and buckling avoided. The positive block consists of a hard lead alloy core round which is pressed the active paste. The negative block is of similar construction and each are wrapped in a layer of glass wool which possesses both insulating and acid proof qualities, while sufficiently porous to permit free access of the electrolyte. The elements being triangular in section, may be made up into either round or rectangular groups, and are afterwards bound with insulating bands.

For train lighting the cell is usually made in a circular form, which when placed in a square box allows plenty of room for electrolyte.

It is claimed that this cell has very great recuperative powers, and that even when fully discharged (to 1·5 volts),

there is such a reserve of latent energy owing to the bulk of the active material being unaffected, that it can immediately afterwards give its full voltage. The recovery is due to the cell being really only partially discharged, and this prevents sulphation.



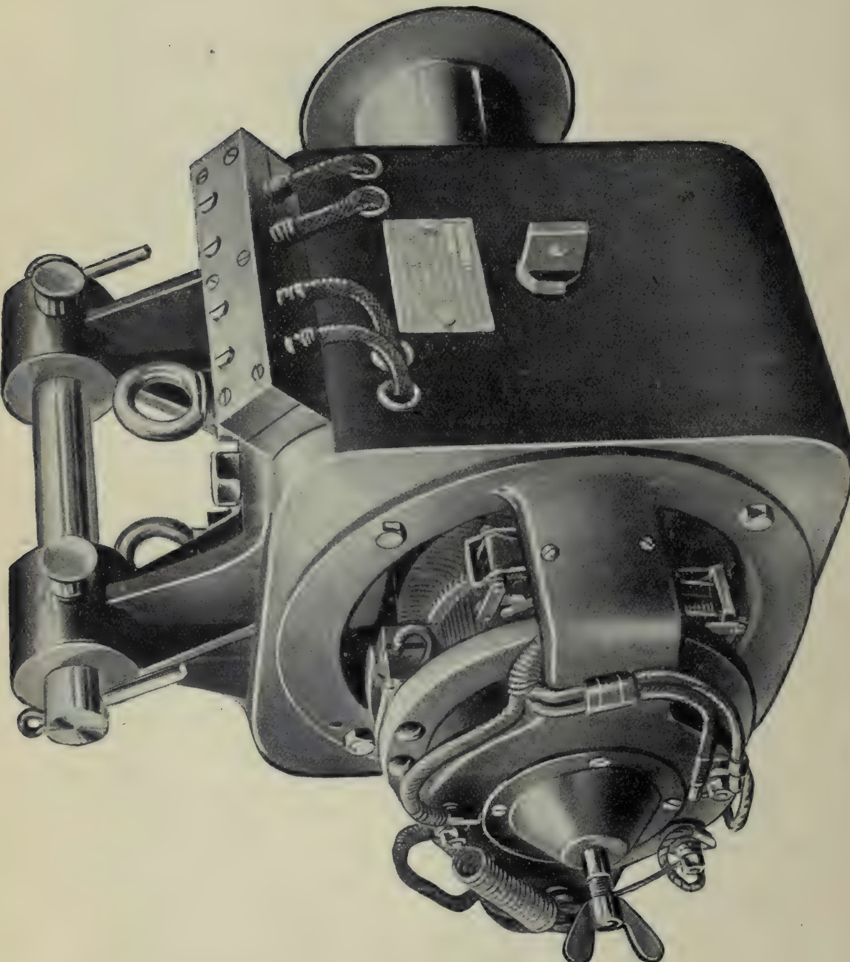
FULLER BLOCK ACCUMULATOR.

Fig. 25.

ELECTRIC FAN EQUIPMENTS.

Although all systems of electric train lighting are of course applicable to the driving of fans, or in fact, any other use within the limits of the current and voltage supplied, it is often required to fit ventilating fans to existing gas lighted carriages. In tropical countries fans are a necessity, and old gas lighted carriages can readily be brought up-to-date by fitting incandescent burners, and a fan equipment. No great amount of voltage regulation is required for driving fans, and consequently the usual auxiliary regulator can be dispensed with, resulting in a saving of first cost. A typical fan equipment is that supplied by The Pintsch Electric Manufacturing Co., and shown in Fig. 26. The dynamo has an output of 25 amperes at 24 volts and this will suffice for an ordinary bogie carriage with say 8 or 10 fans, provided these are not extravagent in the use of current. The armature is series wound, and of simple but robust construction, running in universal ball bearings, and suitable for high speeds. It is self-regulating, by the method described in the Pintsch Lighting system, and the difference in the speed of the fans, between the dynamo "cutting-in" and the highest train speed, amounts to only 10 per cent. which is inappreciable. A single battery only is used, and the dynamo is connected with this, at the correct voltage, by a solenoidal switch, Fig. 27, excited by the dynamo current. Where a large fan load is used with a lighting equipment some systems provide for the lighting current only being regulated closely, the fan current being taken direct from the dynamo, the auxiliary regulating device being then smaller than it would otherwise be.

Messrs. Pintsch also manufacture a ventilating fan which is largely used, and typical in design and appearance of the usual railway carriage fan. It is fitted in gimbals on a bracket, and is therefore capable of universal movement and can be used either as a bracket fan, or attached to a ceiling.

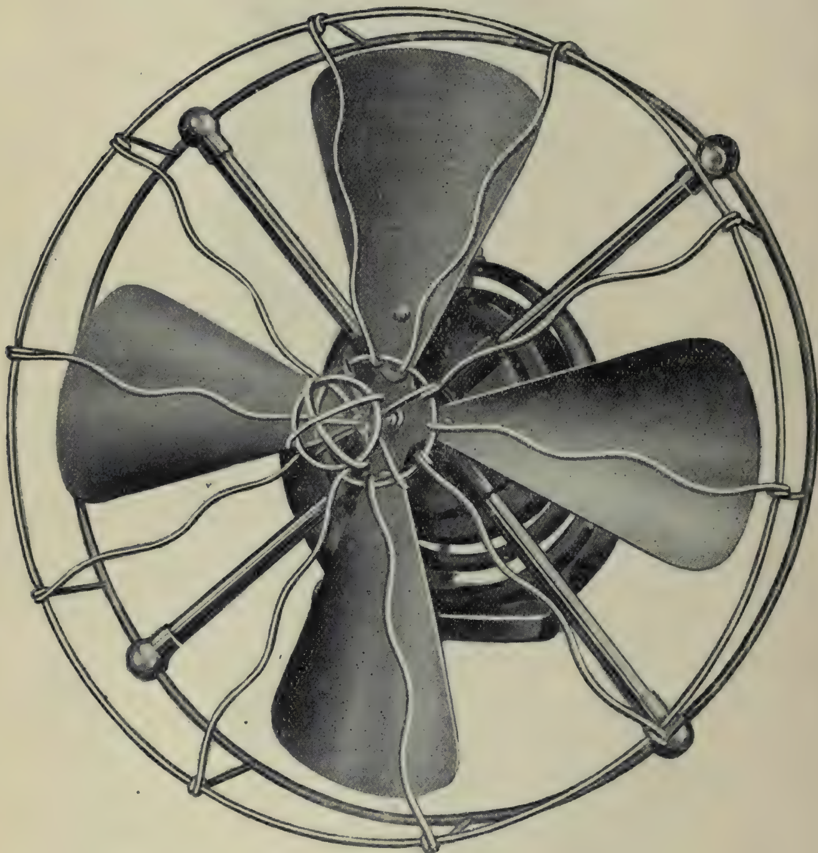


PINTSCH FAN DYNAMO (Dust cover removed). Fig. 26.

PINTSCH FAN EQUIPMENT. Cut-in Switch.

Fig. 27.

The armature runs in ball bearings and the brushes are arranged so that they can be quickly examined or renewed, while the fan motor carcase is dust-proof. The current consumption of a Pintsch fan with 16 inch diameter blades is only 1·65 amperes at 24 volts or 39·6 watts. The fan is swivelled in the direction required by means of the handle on the guard, and to prevent the guard working loose, a very rigid connection is made to the body of the motor. A small regulating resistance is used in connection with the switch, so that passengers can suit the speed of the fan to their requirements. The fan is shown in Fig. 28.



PINTSCH VENTILATING FAN.

Fig. 28.

MAINTENANCE.

The maintenance in good order and condition of electric lighting equipments requires a well-organised system. Conditions will, of course, vary with the number of equipments, length of railway, nature of service, etc., but even if but a few electrically-lighted carriages are in operation some special attention must be given them. The first requirement is that the dynamos, regulating devices and batteries must be regularly inspected, and this is usually easy of accomplishment if the carriages are inspected at the termination of their journey, as in most cases, trains are then put into sidings for washing and general examination.

If the line is a short one, and carriages do not run any considerable distance, this examination would probably be sufficient if carried out two or three times a week. On a long line running considerable distances, the usual train examiners can include in their general examination of passing trains, the belt, and running gear of electrically-lighted carriages. More than this cannot as a rule be done, but junction examiners, before passing a carriage to a foreign line, should satisfy themselves in addition that the lamps will light properly.

At the terminal station, where more time can be given, the dynamo should be regularly lubricated and cleaned, the automatic devices inspected and the battery examined and watered if necessary, the specific gravity of the electrolyte being taken about once a fortnight if possible.

Should the lights of a carriage be found out of order, the necessary attention must be given at the earliest opportunity. Small repairs may sometimes be done en route, but, as a rule, the carriage is run to the terminal or depôt, where the electrician or fitter is stationed. Here should be stocked spares of those details of the equipments likely to require replacing, and the fitter undertaking the repairs should have been specially trained in the subject.

It is important that the periodical overhauling of the batteries should not be overlooked, and to prevent this, a board should be prepared on which the numbers of the carriages are painted, as in Fig. 29. Columns are arranged for the months of the year and small holes drilled in the squares. In these are placed large-headed pins, the heads being painted different colours.

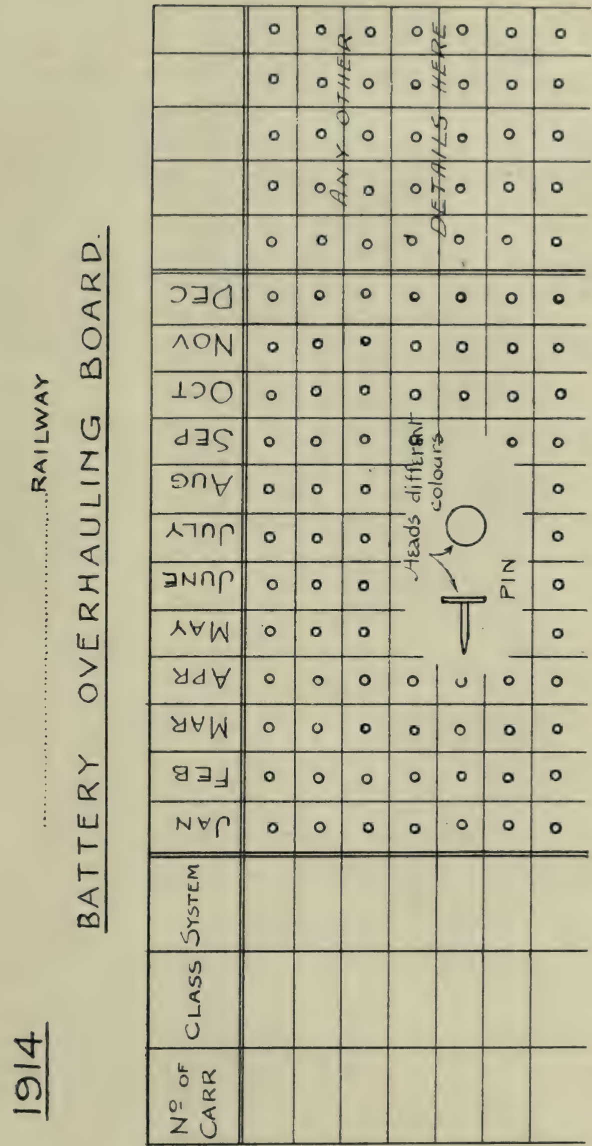
Thus, when a battery is first put into service on a carriage, this could be indicated by a white pin, which might be changed for a red one on the battery being washed out. A glance at the board would show how the work of battery overhauling was progressing and which carriages should be taken in turn.

The system can easily be elaborated, so that other useful data can be recorded. Thus, other different coloured pins may indicate different depôts at which the work was done, while in additional columns could be recorded dynamo failures, belts used, etc., etc.

On a large railway having a number of examiners some method of reporting and recording their work is necessary. Systems differ, but perhaps that in use on the Great Western Railway is as complete as any. The men enter particulars of the work they do on a printed card, which is sent daily to the head office. The information on these cards, belts used, lamps supplied, etc., is entered against the number of the carriage on a large sheet. In this way it is possible to see at once whether any particular equipment is giving more trouble or requires more spare parts than others.

When a partial or total failure of light takes place, the examiner, after attending to it, reports it on a special form, giving full particulars of cause, etc., so that the matter can be investigated by the head of the department and a recurrence perhaps prevented.

Many failures are due to faults of other departments. Thus, guards may omit to switch the lights off and run the battery down. This failure would be reported to the Traffic Department with a view to having a similar occurrence prevented.


1914
RAILWAY
BATTERY OVERHAULING BOARD.
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AUG
SEP
OCT
NOV
DEC
ANY OTHER DETAILS HERE
Heads different colours
PIN

Fig. 29.

Every effort should be directed toward preventing a failure of light, as if this occurs, serious inconvenience is caused to a number of passengers. It is therefore necessary that every part of an electric lighting equipment should be thoroughly examined at intervals, as very small irregularities in the working of some details may mean the total absence of light.

When a battery is examined the specific gravity of the electrolyte in each cell should be entered in a book for reference, and compared with those obtained on the previous occasion. Thus, if the gravities show a rising or falling tendency, steps can be taken to modify the charging current accordingly.

The condition of the dynamo can usually be ascertained by inspection. In some cases it is possible to motor the dynamo by the battery current, so as to make sure that it is able to generate, but it is better not attempted, as the danger of burning out the armature is always present. If in any doubt a test for continuity can always be made by an ordinary galvanometer.

LIGHTING DETAILS.

Illumination is required in a railway carriage when daylight is not available, and the practical aim must be to place the light in such a position as to utilize the light-giving property to the utmost, and at the same time to impart a pleasing form or design to the fitting supporting the illuminant.

The rays emitted by any bare source of light are distributed fairly evenly in every direction from the source of light, but as certain portions of a railway compartment require more illumination than others, it is necessary to re-direct the light rays. The sources of light should be located so that they will give the greatest amount of light where needed without coming within the range of the passenger's vision. In addition they must be placed where least liable to damage.

A location which would be ideal for one compartment, might be unsatisfactory in another carriage, but undoubtedly the most important consideration is the one of providing the best illumination.

A desirable feature in the construction of lighting fittings, is accessibility of the various details. Should a light be found out of order its repair or renewal has very often to be effected within the limited time allowed by service stops. Unless the fitting can be quickly taken apart, the defect would have to be passed over until sufficient time was found to remove the fitting altogether. As an illustration, in many designs of fitting, should the leading in wires to the lamp holder break, the whole fitting must be dismantled before a joint can be re-made. Fittings for railway service also require to be stiff and strong, or they will vibrate excessively and cause the lamp filaments to break.

For ordinary compartments with elliptical or round roofs a very good form of fitting is that shown at A Fig. 30. These give the maximum of head room, and with white enamelled reflectors, show a very good light. In an ordinary 3rd class compartment one of these fittings, enclosing two 10-candle

power lamps is usually sufficient. For 1st class carriages a more elaborate design is desirable, and 2-light ceiling fittings as shown at B Fig. 30 are very suitable. In some cases 4 or 5 single-light fittings are arranged, but although these may result in a better diffusion of light, the additional wiring is a disadvantage. For clerestory or "deck" roofs a longer fitting must be installed, and for superior class carriages the type shown at C Fig. 30 is suitable. Bracket or shoulder lamps under the luggage racks are not to be recommended as they not only produce a glare in the eyes of passengers sitting opposite, but are very liable to damage when putting luggage in the rack. In addition the lamps, shades, etc., can be easily stolen.

Corridor lights should be of a similar type to Fig. C, but smaller, and units of 8 candle power each are usually sufficient.

For lighting Parlor and Buffet cars some distinction must naturally be made in the fittings consistent with the increased convenience and additional refinement found in these cars. There is probably no class of railway carriage where reading is more indulged than in the Parlor car, as comfortable seats or chairs are provided, and these are usually capable of movement, so that the passenger can adjust his position with regard to the light. For this reason the lighting fixtures should be preferably placed along the centre line of the ceiling, the passenger can then face the windows while the light is thrown over the shoulders.

In the lighting of sleeping cars, in addition to the usual general illumination, berth lamps are the most suitable form of fitting, and each berth should be provided with one, so arranged that should its occupant wish to read, the light is concentrated on his paper without causing annoyance to the occupants of the other berths. The fixture must also be fitted nearly flush with the side of the car, otherwise the passenger is liable to strike it with his head. Individual switches are of course provided. A suitable type of berth lamp is shown at D Fig. 30.

Fig. 30.

Luggage and baggage vans require lighting fixtures which allow the greatest head room, otherwise they are likely to be damaged by luggage carried on porters' shoulders. A flat ceiling fitting protected by a wire guard as E Fig. 30 is suitable, or in special cases side (bulk-head) lamps. Lights in baggage rooms are often wired in a separate circuit so that they can be put out between stations by the guard.

For Dining, Restaurant and Buffet cars a good general ceiling illumination gives the best results, 3 or 4 light electroliers along the clerestory or centre of ceiling having a pleasing appearance. Over the dining tables a more local illumination is desirable, and this may be supplied by side bracket fittings or table lamps. The latter F Fig. 30 are much appreciated by the public, but in addition to taking up the minimum amount of room on the table, should be of strong and solid design otherwise they are likely to be knocked over. As they are often moved when cleaning the car, the flexible connection, wall socket and plug fitting should be of good quality, or defects and short circuits will soon become troublesome.

In the Kitchen, strong and serviceable ceiling fixtures, with enamelled steel reflectors are recommended, as owing to steam, grease, etc., more frequent cleaning is required, and the light fittings are subjected to rough usage. An exhaust fan fitted in the roof conduces greatly to the comfort of the kitchen staff and also greatly assists in keeping the smell of cooking from penetrating to the Dining Saloon.

Postal vans require to be well lighted, and the lamps must be placed in the best positions with regard to the sorters' tables, etc. Although every effort should be made to obtain the maximum amount of illumination, the fittings must be of a strong and simple type as G Fig. 30.

For lighting car end vestibules a centre light is usually fitted, but has the disadvantage that a shadow is cast on the steps in advance of the passenger, and on occasions when

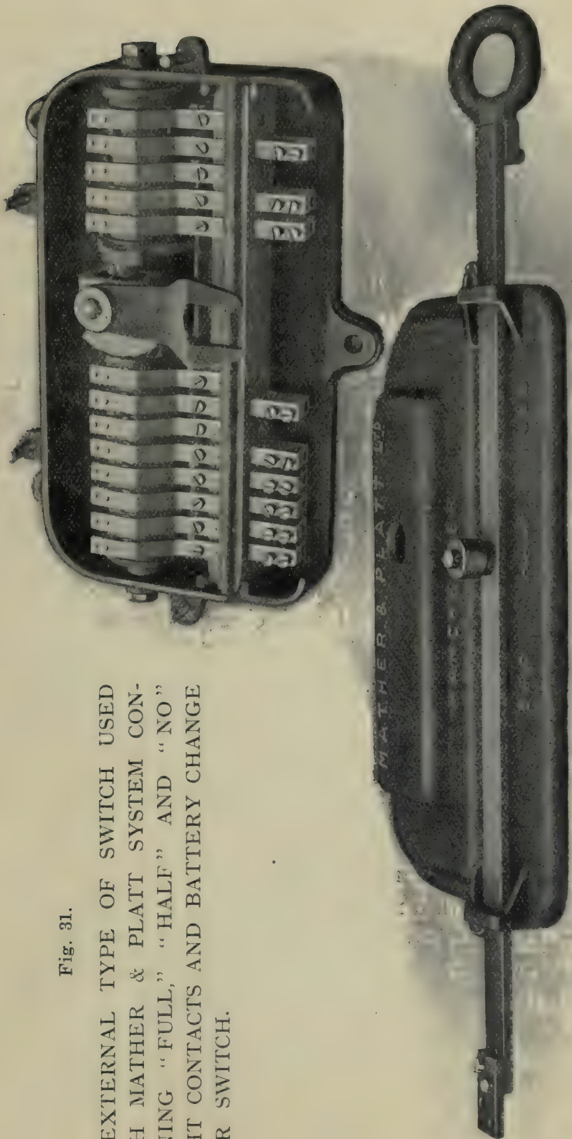

Fig. 31.

EXTERNAL TYPE OF SWITCH USED WITH MATHER & PLATT SYSTEM CONTAINING "FULL," "HALF" AND "NO" LIGHT CONTACTS AND BATTERY CHANGE OVER SWITCH.

light from the station platform is not available, may make the descent from the car dangerous.

Side lamps are therefore provided, fixed in recesses over the steps, but care must be taken that these are placed so that they do not interfere with the system of tail-light signals should the car be at the end of the train.

The main switches of electrically-lighted carriages are usually external, and placed on one of the ends. The switch is in appearance similar to the main cocks fitted to gas-lighted carriages, and is operated in the same manner, thus preventing confusion and wrong switching when operated by the ordinary station staff.

Half lights or full lights can be readily obtained. In some systems the switch is also arranged to perform other duties and the Mather & Platt switch box shown in Fig. 31 is a typical case. The ordinary backward and forward movement of the switch handle in a horizontal direction rotates the commutator or barrel and changes over the batteries each time the " full light " position is changed to " no lights."

In sleeping cars, dining cars, etc., in which attendants travel, internal switches are usually provided, and consist of a number of contacts arranged in circular form, which are bridged by a rotating handle. This switch is preferably kept in a locked cupboard.

Where it is necessary to supply lights during the daytime, as in railways with a number of tunnels, etc., a master switch may be installed in the guard's van to operate magnetically the main switch of each carriage, so that the guard can, as required, light or extinguish the lamps of the whole train.

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